DETERMINING THE EFFECTIVENESS OF DESIGN GUIDELINES AND A PRODUCT EVALUATION TOOL IN FACILITATING ECO-DESIGN

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DETERMINING THE EFFECTIVENESS OF DESIGN GUIDELINES AND A PRODUCT EVALUATION TOOL IN FACILITATING ECO-DESIGN

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Industrial design is a profession almost entirely dedicated to the design and development of physical goods and material culture. It is a practice that has thrived since industrialization, when the mass production of goods allowed average people the chance to afford products that improved their life style. Industrialization has chosen the path of least resistance and focused on the sheer volume of growth and high net profits without regard to efficiency or conservation on a macro level; especially in regards to energy use including fossil fuels. Companies are likely to choose to focus efficiencies in production and supply chain management on a micro-level within the company itself in order to help improve their bottom line profits.

Nature has mastered the philosophy of doing more with less in order to survive, and soon designers will be encouraged to follow suit. With population increasing, energy prices rising and non-renewable resources being consumed at higher rates designers will have to adapt their industry to fit a more conservative, responsible model. Many manufacturers are leaving a devastating legacy of toxins and waste behind while passing off the consequences to future generations. At this point in time commerce and industry are growing faster than nature and unfortunately nature is on the losing end.

As product designers, we have the ability to shape the environment and slow down environmental degradation more than economists, politicians, businesses and even environmentalists (Fuad-Luke, 2004). We are at the root of

the problem which is our society's consumption habits. The power of designers is catalytic and the impacts of our decisions multiply exponentially with every manufactured product. Unfortunately the decisions we make are not always focused on the welfare of the environment, in fact they rarely ever are.

This research project aimed to determine the effectiveness of guidelines and a product evaluation tool in helping to facilitate environmental design principles for practicing industrial designers. The term for environmentally responsible design is referred to as "eco-design" and it is defined as being a design process that considers the impacts associated with a product throughout its entire life cycle from acquisition of raw materials through production, manufacturing and use to end of life. Throughout the research project guidelines and an evaluation tool were developed and tested by graduate industrial design students for usability as well as effectiveness in positively influencing the environmental impacts of product designs.

CHAPTER 1

INTRODUCTION

Industrial design is a profession almost entirely dedicated to the design and development of physical goods and material culture. It is a practice that has thrived since industrialization, when the mass production of goods allowed average people the chance to afford products that improved their life style. Industrialization has chosen the path of least resistance and focused on the sheer volume of growth and high net profits without regard to efficiency or conservation on a macro level; especially in regards to energy use including fossil fuels. Companies are likely to choose to focus efficiencies on a micro-level within the company itself in order to help improve their bottom line profits.

In the book, “The Ecology of Commerce: A Declaration of Sustainability” Paul Hawken compares industrialization in developed countries to an immature eco-system. It starts off in a barren field where shrubs and weeds devour resources to cover the ground as quickly as possible. There is minimal diversity among the initial plants which live short life spans, transform the environment dramatically, use up all the resources and leave a lasting impression. Over time, however, the eco-system evolves into a pioneering mature state. Larger trees enter the system and challenge the smaller shrubs, turning the field into a forest. Here resources are used efficiently and relationships with other organisms are optimized. Also in the forest there is a wide range of diversity and many animals and insects rely on the trees and plant life for survival. From year to year there is not much change in the forest, although the same land and resources now support significantly more biomass than when the shrubs and weeds first took over. Industries and designers could follow the examples of nature and produce higher quality, durable products that require fewer material and energy resources. Nature has mastered the philosophy of doing more with less and soon designers will be encouraged to follow suit. With population increasing, energy prices rising and non-renewable resources being consumed at higher rates designers will have to adapt their industry to fit a more conservative, responsible model. Many manufacturers are leaving a devastating legacy of toxins and waste behind while passing off the consequences to future generations. At this point in time commerce and industry are growing faster than nature and unfortunately nature is on the losing end.

Now is a crucial time for developed countries to reform industrialization, set environmental standards, and serve as an example for developing countries in Asia and Latin America. Although the world's richest countries make up only a fifth of the global population, they account for 45% of meat consumption, 58% of energy use, 84% of paper use and 87% of vehicle ownership (Ursula Tishner, 2001).. The poorest fifth of the world's population, which is more than a billion people, still lack basic life sustaining needs such as food, shelter, housing, water, sanitation, and electricity. Every day the worldwide economy burns an amount of energy the planet required 10,000 days to create (Hawken, 1994). In the coming years if developing countries adopt the business models and consumption models of most current western societies, the environment will suffer consequences that may be irreparable. Since many of the energy sources and material resources used in manufacturing are nonrenewable, it is inevitable that one day there will be a shortage of resources and energy. Instead of finding a solution to the problems of tomorrow we are ignoring the affects and bypassing the problems by harvesting resources at higher rates than ever before. This inaction is having detrimental effects on the environment that may never be reversed (Hawken, 1994).

Although “environmental design”, “eco-design,” “eco-efficiency” or “green design” all concentrate on the environmental impacts of product design, there are several more entities at risk other than the environment. The economy, government and even world peace all stand to benefit from the manufacturing of greener, more efficient products (Hawken, 1994). Economies will grow stronger as products are created that require less energy, resources and materials to manufacture, and less energy to use and transport. Companies that develop these efficient products will have a lower overhead, will likely attract more investors and will be more likely to compete on a global stage with products from other countries. A recent example of this can be seen in the competition between Japanese automakers and American automakers at a time when fuel prices reached record highs. In early 2009 Toyota surpassed GM as the largest automaker in the world; a title which GM held for 77 consecutive years. This is due in part to GM’s global shares decline of 10.8% in 2008 compared to Toyota’s 4% drop (El-Hasan, 2009). Japanese cars are widely known to be more fuel efficient than their American and European competitors. For example, according to FuelEconomy.gov the most fuel efficient vehicle across all categories is the Toyota Prius with as estimated 48 miles per gallon in the city and 45 miles per gallon on the highway (Agency, 2009). Fuel economy has proven to be a necessary advantage in a time of world-wide economic struggles and higher-than-ever fuel prices.

In addition to economic advantages, eco-efficiency can also benefit governments which will be able to profit from reduced spending on regulatory enforcement and environmental efforts. With the implementation of efficient design and manufacture, United States' national security will also be stronger without the soaring dependence on foreign oil from countries that threaten our democratic state.

A lesser known advantage of eco-design is a reduced rate of resource shortage and conflicts in the developing world. Scarcities of renewable resources are already contributing to violent conflicts where shortages of water and fertile land occur. A project regarding environmental change and acute conflict conducted by the American Academy of Arts and Sciences and the University of Toronto, predict that in the coming years, if preventative action is not taken, the conflicts will undoubtedly escalate as a result of rapidly expanding populations in conjunction with resource depletion (Hawken, 1994; Homer-Dixon, 1991). An example of this can be seen in the Philippines where a growth rate of 2.5 percent has contributed to the government's encouragement of large scale low-land agriculture which has displaced many peasants. Many have migrated to the steep and ecologically vulnerable uplands where they have cleared land for living. This has caused repercussions such as erosion, falling food production, and further clearing of land. The shortage of fertile land has contributed to poor economic conditions for peasants and civil unrest in peripheral areas lacking in government control (Homer-Dixon, 1991).

As product designers, we have the ability to shape the environment and slow down environmental degradation more than economists, politicians, businesses and even environmentalists (Fuad-Luke, 2004). In our efforts to create ever more desirable products we have directly encouraged our society's consumption habits. In 1996 80% of Americans believed they consumed far more than they needed, however there have been no mainstream cultural movements to reverse our actions. Our consumption habits have been shaped by material culture and the powerful influences that fuel these desires such as advertising which is roughly a $435 billion a year industry (Ursula Tishner, 2001). The power of designers is catalytic and the impacts of our decisions multiply exponentially with every manufactured product. Unfortunately the decisions we make are not always focused on the welfare of the environment, in fact they rarely ever are.

There are a wide range of career opportunities for industrial designers, however most practice product design for a corporation, a design consultancy or through freelancing. Although the setting for their work may be different, all designers are challenged to create products that will satisfy clients, consumers, marketers or management. Only a small fraction of product designers can be considered experts on issues regarding the environment and eco-design principals. Instead, they are more driven by the needs of those that deem their products success; the clients and consumers.

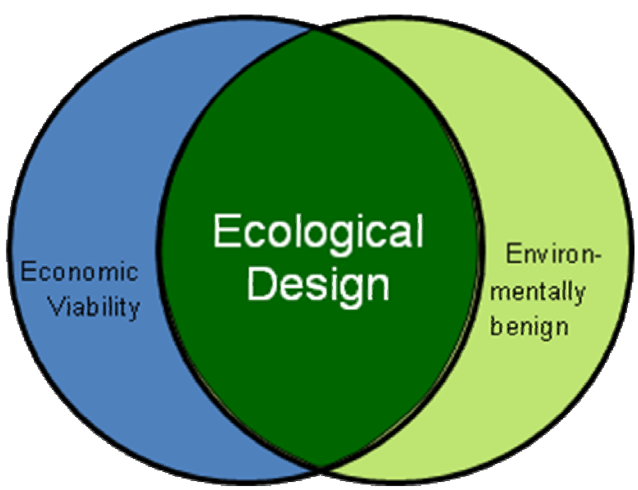

Figure 1: Ecological Design Diagram

The author of *EcoDesign the Sourcebook* defines “eco-design” as being a design process that considers the impacts associated with a product throughout its entire life cycle from acquisition of raw materials through production, manufacturing and use to the end of the product’s life. Eco-design also ‘seeks to improve the aesthetic and functional aspects of the product with due consideration to social and ethical needs’ (Fuad-Luke, 2004). Therefore, eco-design is not in opposition to creating a functional and aesthetically pleasing product, but is rather about being conscientious of the impact of products throughout their life cycle. The biggest challenge is the fact that industrial designers may not be able to access the information they need to design under principles of eco-design. Steve Belletire, co-author of the Okala guidelines (See Literature Review: 2.1 Design Tools) and professor of industrial design at Southern Illinois University at Carbondale described ecodesign as designing a product that is environmentally benign as well as economically viable (see Figure 1)(Belletire, 2008).

In a 2004 survey conducted by the Industrial Designers Society of America in conjunction with the US Environmental Protection Agency, 95 practicing industrial designers answered questions about their level of need for ecological and sustainable design information. The top three greatest needs among the designers were information regarding: International Environmental Regulations, Comparison of Environmental Impact of Processes, and Comparison of Environmental Impact of Materials. (White, 2004). There were several other topics that designers expressed need for including, Ecodesign Education, General Eco-design and Sustainable Design, and Green Market and Consumer Research. It is likely that traditional industrial design education, in the past at least, did not focus on environmental design strategies, essentially requiring designers to actively search out this information once they are practicing in the industry. This illustrates that there is a need for eco-design guidance that is easy to apply and will help develop cost effective products with a lessened impact on the environment.

Purpose

The purpose of this research was to test the effectiveness of a new system of design guidelines and a product evaluation tool in assisting practicing industrial designers. Through the implementation of this tool, the goal is to help designers apply eco-friendly design alternatives and innovations and educate them on the impacts of their decisions through an evaluation scheme.

Specific Aims

In order to develop a tool that puts much needed information in the hands of industrial designers, there were several project aims that needed to be accomplished. The first phase of the research aimed to determine what areas of product development industrial designers had control over so that the tool could offer relevant suggestions for design improvements. Next, the actual environmental principals and ecodesign strategies had to be included. To find this relevant data, several sources such as existing tools and guidelines and ecodesign experts were consulted. After the tool was created, the next aim was to test the tool for effectiveness in facilitated ecodesign.

In May of 2003 the Industrial Designers Society of America (IDSA) and Silicon Valley Toxics Coalition sponsored a survey regarding Electronic Product Ecodesign Influence which sought to determine the perceived level of influence that designers have over the environmental consequences of their products. Fifty-two designers responded to the survey and when asked what design attributes the designers were most able to influence, ‘Form, color, texture’ and ‘Finish type’ ranked as the top two responses (Davis, 2004). This information along with interviews of practicing designers helped determine what types of decisions designers had influence over and therefore what information should be included in the guidelines.

To develop a comprehensive source of ecodesign principals, research was gathered on existing ecodesign tools and software as well as literature on environmental principals relating to design and manufacturing. After filtering through the information and selecting information that was both relevant and feasible for designers the guidelines and tool were distributed to graduate student designers to test for usability and effectiveness (See Methods 3.3 Testing the Tool). The designers used the tool to evaluate a finished project, and then used the guidelines to assist them in an upcoming project. Feedback from the student designers was recorded and appropriate refinements were made to the guidelines and evaluation tool.

This research and the development of these ecodesign tools were crucial because they could eventually help promote efficiency in production and transportation, conservation of materials and resources and alternatives to harmful materials that might have been used otherwise. In addition to obvious environmental benefits the tools could also help encourage design alternatives which could lead to value-added innovations for products such as energy efficiency.

The end goal of the research was to acknowledge the designer as a catalyst for environmental change and allow them to take action by giving them access to a comprehensive and effective set of design guidelines and evaluation tool. The tool will help assist them in the development of more environmentally conscious products. Each design improvement may have a negligible impact on the environment, however when all the impacts are combined for every product purchased or currently in use, the environmental benefits multiply and suddenly the designer has a role in the reversal of environmental degradation.

CHAPTER 2

LITERATURE REVIEW

2.1 A Brief History of Ecodesign and the Progression of Eco-Products

To successfully develop ecodesign tools for industrial designers it was important to understand the history of ecodesign in the field of industrial design and how it related to the environment. It was also important to understand the progression of eco-friendly products to see what the motivating factors were for going green as well as how they were accepted among consumers.

Today it seems that every industry in some way or another is pushing to be more ecologically aware, whether it is through recycling, efficient manufacturing or sponsoring environmental stewardships. Companies realize that some consumers value corporate responsibility and often reward them with their wallets. Although most companies attempt to improve their eco-image, prior to the mid 1990's no major piece of environmental legislation had ever been supported by Corporate America (Hawken, 1994). It seems as though the companies that are often the most successful are the companies that take risks and overstep their boundaries exceeding their capacity in order to make the highest profits. Companies have very little reason, if any, to account for their present demands on energy and material resources so they often operate today at the expense of future generations.

The culture of corporate responsibility varies from country to country. Germany and Japan, for example, happen to be two of America's most successful competitors and companies in those countries tend to operate much more efficiently because resources are fewer and costlier. Since their availability of resources is more limited, these corporations have adapted their business models to be less wasteful and promote conservation and efficiency. Although their motives may be more financially driven then environmentally driven, conservation and efficiency are both beneficial. For example, in

Figure 2: Wassily Armchair

the 1920'-s Marcel Breuer, a notable German Bauhaus designer used lightweight steel tubing for furniture design. This led him to his most widely-known design, the Wassily armchair, which is shown in Figure 2. He saw a need for a durable and inexpensive chair that could be packed flat for efficient transportation.

In other instances material shortages may have only been temporary, but still had a lasting impact on product design. From the 1940's-1950's for example, Europe and the United States suffered from shortages of materials and energy due to World War II. This period of resource shortage provoked a design movement based on the "less is more" philosophy (Fuad-Luke, 2004). Other types of social circumstances and movements have the ability to change products. The Hippie movement of the 1960's questioned consumerism and drew on various back-to-nature themes. The culture was interested in world peace, sustainable living, sustainable energy and natural materials.

Hippies embraced the back-to-nature lifestyle by shunning mass consumption and commercialization.

It took several years for consumers to realize the affects of industrialization and inefficient manufacturing on the environment. Amidst various outreaches of support by governments and companies to promote ecological awareness, several marketers saw opportunity in green marketing. In a one year period between 1989 and 1990 green marketing claims quadrupled (Ottman, 2004). This outpouring of green claims resulted in consumer skepticism, confusion and uncertainty over which products were actually eco-friendly. There was a backlash towards the pioneering green marketers from environmentalists, regulators and the press over what was perceived as inconsistent and misleading labels and claims. This movement of irresponsibly assigning eco-friendly claims to products is commonly referred to today as “green washing.” The positive result of this over-abundance of eco-friendly claims was the realization that making justifiable environmental changes involved more than tweaking one or two product attributes and dressing up the packaging. The public backlash served as a lesson that ecological awareness begins with corporate commitments and values. Deb Johnson, academic director of sustainability at New York’s Pratt Institute design school acknowledged the need for mass produced green instead of niche market green. In a Wall Street Journal article from 2008 Johnson said, “The invisible side of goods- the manufacturing- needs to be green too, and these products must go mass-market to have much impact on the environment. Products such as ottomans and bathmats made from recycled flip-flops are whimsical and interesting, but it’s not doing things at the deepest level” (Lin, 2008).

In addition to corporate-wide commitments, another way to justify eco-friendly marketing claims is to get third party approval or certification. Several product certifications, both non-profit and for-profit, exist for the sole purpose of marketing the products and helping consumers make ecologically aware purchasing choices. Some of these certifications involve scientific comprehensive analyses while others are more subjective in nature.

In the early 1990's in the Netherlands, Philips Electronics, the Dutch Government and the Technical University of Delft collaborated to develop Life Cycle Analysis (LCA), one of the first product and process analysis systems. Their software, IDEMAT LCA, would become the first of its kind to be widely used by designers to measure the overall impact of products throughout their lifecycle. Before this point there was no widely accepted, holistic assessment of products available (Fuad-Luke, 2004). The system involved an in depth look at the product including all inputs and outputs of the whole product life cycle. Due to the rigorous and time intensive requirements, it was not a practical analysis for all products.

Prior to the mid 1990's it is clear that there still was mixed motivation to incorporate ecodesign principals throughout mainstream industrial design, and there was still some skepticism among consumers. Victor Papanek, a pioneer in the ecodesign movement published several criticisms of the design industry in his 1995 book, *The Green Imperative*. He confronted the design profession demanding that they face their social responsibilities instead of selling out to commercial interests. Papanek, argued that although environmental effects are global, it is necessary to begin repairing the damage by 'healing on a human scale' (Papanek, 1995). Often it is the size and scope of manufacturers and corporations that prevents them from being open to change. The individual has a much faster response to changes and the positive effects can be applied to products immediately. Papanek made a grim observation about the design profession by saying, “Unless we learn to preserve and conserve Earth’s resources and change our most basic patterns of consumption, manufacture and recycling, we may have no future” (Papanek, 1995). This statement could be true for both our profession as designers as well as human civilization in general.

Consumer culture, in a large way, dictates how designers approach product design. In the 2004 book *Eternally Yours- Visions on Product Endurance* the authors examine the reasons why some objects are thrown away and others are cherished. Increasing the lifetime of a product (which is an ecodesign principal) keeps objects out of the landfills and also enforces a reduction on demand for new products and manufacturing. Design was first developed as a utilitarian profession and the products that were developed were strictly embodiments of function. Their main criteria was that they worked properly and were able to be mass produced (Hinte, 2004). Products were bought purely for function; therefore they were more likely to be thrown away or replaced because there was no bond or attachment to the user. In the post-modernism movement, instead of reducing products to their function, they are reduced to their meaning. Products communicate as icons, symbols or signs. Durability is no longer important because function has been surpassed by convenience and fashion. As stated in *Eternally Yours- Visions on Product Endurance*, to increase the product’s lifetime, designers must conquer the task of creating things that invoke meaning and user attachment, but that are also durable.

In summary, throughout the past few decades there have been mixed opinions about which level of a business model the eco-design principals should be applied. Some feel that it should be a corporate wide commitment, although others feel that the actions of designers can have a more direct impact on products then upper level management. In either scenario applying ecological principals will help slow down environmental degradation and improve the value of products as well as the quality of life. Getting individuals and corporations motivated to make these changes could, however, be the hardest struggle of all. In a 2003 survey by IDSA titled “Electronic Product Ecodesign Influence” 52 practicing electronics designers were asked about perceived quality priorities in products. Factors that ranked the highest on a 0-4 scale were “Quality/Performance” with 3.6 and “Appearance” with a 3.3. “Environmental Impact” was at the bottom of the list receiving a score of 1.0 (Davis, 2004). This survey indicates that the environmental impact of products is not seen as an indicator of quality among electronics designers. Hopefully these quality judgments will change once designers realize that ecodesign principals can be applied to products to help them operate efficiently, last longer and conserve material resources.

2.2 Existing Ecodesign Tools

After researching the history of industrial design and various environmental movements, the next step was to research existing ecodesign guidelines and evaluation tools. As seen in Figure 3, the findings were narrowed down into three main categories of information for ecodesign.

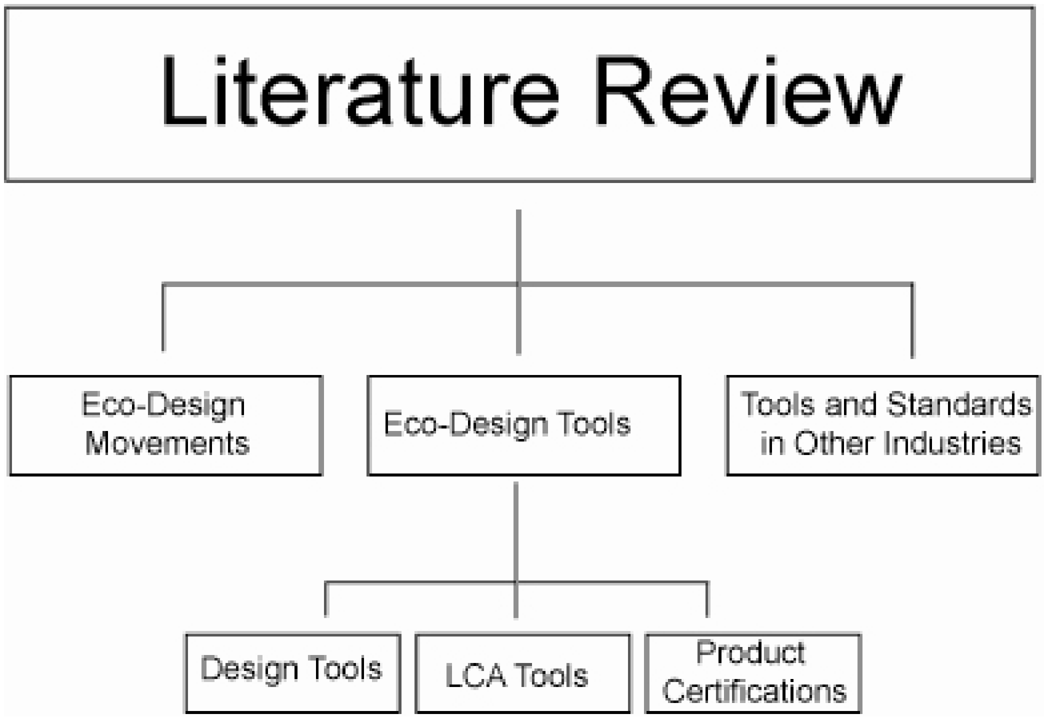

Figure 3: Literature Review Diagram

First there were *Design Tools* which were specifically developed to help aid industrial designers in ecodesign principals and evaluations. Next there were *Life Cycle Analysis (LCA) Tools* which were more objective and scientific in nature. These required calculations and formulas based on environmental factors and were not necessarily designed for industrial designers. Lastly, there were *Product Certifications* that offered third party justification for environmental claims and sometimes assisted companies in designing eco-effective products. This category of certifications was a reflection on the product and sometimes as well as the brand and was not meant to serve the designer, but the company as a whole.

2.2.1 Design Tools

During the course of researching existing ecodesign tools, there were three fairly well known tools that were discovered through online resources including environmental blogs and design blogs and also through industrial design organizations and industry experts.

The first design tool researched was one of the most recognized and comprehensive; IDSA's (Industrial Designers Society of America) Okala Guidelines. IDSA, a nationally respected design association serving industry professionals and students, has realized the enormous opportunities to reduce ecological damage through product design. Through partnerships with *BusinessWeek* magazine and the US Environmental Protection Agency, IDSA has developed ecodesign awards, conducted research studies on the subject and developed a curriculum for ecodesign education. This design tool is among the most recent ecodesign material with its latest revision in 2007. The Okala commitment to making ecological design easy to understand and easy to teach is fostered through their creation of guidelines and introductory course on ecological design. There is also an emphasis placed on increasing understanding of the significance of design in 'the global ecological crisis' (IDSA, 2007). Okala combines ecodesign principals with an LCA-like evaluation system. The guidelines discuss the lifecycle stages of a product in relation to environmental impact categories. The environmental impact categories include Ecological Damage, Human Health Damage and Resource Depletion. The guidelines also offer general underlying ecodesign strategies which include: Innovation, Low-Impact of Materials, Optimized Manufacturing, Efficient Distribution, Low-Impact Use, Optimized Lifetime, and Optimized End-of-Life.

These ecodesign strategies are further examined with specific examples of how to apply them each to different stages of the product life cycle. This strategy of offering broad, general principals with underlying information and descriptions was a theme that was adopted in the development of this project's guidelines. Several of the actual ecodesign strategies were also used as a framework to form the final environmental principals of this project. In addition to Okala's guidelines and curriculum, it also contains a 'Life Cycle Impact Assessment' that is based on a calculation of 'Impact Factors.' There are several environmental and human health impact categories that are taken into consideration when calculating the Impact Factors including: acidification, fossil fuel depletion, ozone layer depletion and others. Materials and processes included throughout the life of the product from material extraction to end of life are calculated according to the significance of their impacts. The result is a weighted scoring system which indicates the product's total impact. Designers can then calculate their product's score with a chart provided by Okala.

As with any design tool, it was apparent that there were advantages and disadvantages to the Okala system. The impact factors for materials and processes are generalized estimations that may or may not be accurate. As the authors noted themselves, coal-fired electricity plants in China and East Asia are much more polluting then those in the US, Japan and Europe, although the factor points for all locations are equal. In terms of rating transportation as an impact factor, the designer must also know what type of transportation was used to distribute the products as well as how many miles were traveled to be able to assess their product. There are several instances in which the designer has to make an educated guess in order to score their products, and this subjectivity may lead to confusion, bias or inaccuracies.

Although the guidelines and life cycle assessment were developed for designers, they were developed from an educational standpoint in the form of a curriculum. This made quick and immediate application of the principals difficult. In order for a designer to apply these strategies and evaluate their product, there is a learning curve that must be overcome. Also, the guidelines are thorough and comprehensive as they were developed by experts in the industry of ecological design. There is, however, a much heavier interest in toxicity of materials as compared to other impact factors when the product analysis system is calculated. Other impacts such as material conservation, resource conservation and minimizing energy use are not weighed as heavily with the Okala system. After the product impact assessment is completed the result is a score for the impact per hour, or total impact over the life time of the product. This resulting number offers no range of comparison therefore the designer has no frame of reference for which to compare their product's score. Through the analysis of the Okala tool, it was apparent that the system developed for this research project needed to be intuitive and easy to use with an obvious visual indication of the score or environmental impact.

The next ecodesign tool evaluated was the 'Designer's Field Guide to Sustainability' by LUNAR. Based in Monterey, California, LUNAR was listed in *BusinessWeek* magazine as being one of the top ten award-winning American product design firms. A company press release from June, 2008 noted the development of an internal engineering and design initiative called LUNAR Elements which focuses on sustainable design (Design, 2008). One of the initial projects of this environmental task force, led by design director Jeff Salazar, was the cataloging of materials, processes and resources that would lessen the impact of products on our ecosystem. This internal sustainable design initiative lead to the creation of guidelines for sustainable design called the Designer's Field Guide to Sustainability.

The field guide, created for designers and engineers, asks four fundamental design questions about the product concept:

1. What is it trying to accomplish?
2. How is it brought to life?
3. How is it used?
4. Where does it end up?

Similar to the Okala guidelines, this tool is among the most recently created ecodesign initiatives with its 2008 debut. Also, much like Okala, the field guide features fundamental questions that have several underlying environmental principals which can be applied during the design stages to lessen the environmental impact of products. Each of the principles, in the form of a directive statement, has their own easily identifiable icon. The icons serve as visual representations of what the goals are trying to convey. Designers, whose careers are based on visual information, interact with several icons throughout a typical day, so it is an appropriate language to help get the principals across.

The field guide document is also successful in giving specific design-related examples and actual case studies of how to apply the environmental principals as well as possible negative consequences to avoid. The end result of all these characteristics is an easy to access tool for practical application specific to design and engineering industry. Although this tool exists only in guideline form without evaluation parameters, even novice ecodesigners will find it's intuitive and simplistic design applicable.

The last ecodesign tool researched was the IDC Life Cycle Assessment Calculator. This interactive software provides a simple way to assess the environmental impact of a product by calculating its energy input and carbon output throughout the life of the product. Industrial Design Consultancy (IDC) is a product design and development consultancy working in the field of sustainable design and product life cycle assessment (Consultancy, 2008). This design tool is unlike the others previously mentioned because it exists as an evaluation tool without any form of guidelines. The primary objective of this tool is to rate the product at the end of development to determine its energy input and carbon output. The evaluation is calculated through the use of questions that ask the designer certain characteristics about the product, for example, "Does the product contain electronic components?" After the appropriate data is entered for all the product life cycle stages (extraction, manufacture, transport, use and disposal) the results are displayed in relation to energy use and CO2 emissions. The energy use results are illustrated through a bar graph-like output displaying the energy in mega joules. The CO2 emissions are displayed in kilogram figures. Unfortunately the Life Cycle Assessment (LCA) Calculator is another tool in which the final results are displayed in numbers without a frame of reference. The designer can compare between the extraction and manufacture cycle and the use cycle to see which phases use the most energy, however it is difficult to compare the results to other products. This tool succeeds in accessibly because it is a free online resource and easy to use; however, if the designer wants a print out version of the report they must request a PDF mailed from IDC. For immediate product comparison, this is not ideal.

2.2.2 LCA Tools

Life Cycle Assessment (LCA) tools are holistic evaluations of the environmental performance of products and process. They measure all indirect and direct inputs and outputs and cover all phases of the product's life cycle (Assessment, 2008). There are several variations to the LCA approach, however most involve similar steps including:

1. A 'bill of materials' or 'scope' of all materials used for the product
2. An inventory of all inputs and outputs required for all life stages of the product
3. An impact assessment or 'characterization' of the product
4. And lastly some type of interpretation or weighting system to evaluate the product

The Okala LCA approach begins with the 'bill of materials' which is a list of the materials, processes and energy required to make a product, package the product, transport the product and use the product. After the materials and processes are documented, there is an 'inventory' of inputs which accounts for chemical emissions, land-use factors and resource depletion due to the extraction and use of the product's materials. The next step is 'characterization' which converts the inventory emissions into environmental impacts such as acidification, fossil fuel depletion and ozone layer depletion. After characterization the next step is 'normalization' which scales the impacts of the materials according to a certain frame of reference. The Okala LCA system, for example, normalizes the impacts according to the average impacts of a person in North America. The last LCA step is ‘weighting’ which scales the impacts according to the significance of their threat to the ecosystem in a particular geographic region.

The first LCA tool analyzed was the Building for Economic and Environmental Sustainability (BEES) system. This tool was developed through the National Institute of Standards and Technology to help builders, designers and product manufacturers select cost-effective, environmentally preferable building products (Technology, 2007). BEES is a Windows-based software that contains actual environmental and economic performance data for 230 building products. This tool is meant to help businesses select materials that are ecologically friendly but also cost effective over the lifetime of the product. All stages of the product life cycle are analyzed and economic performance is measured based on the cost of initial investment, replacement, operation, maintenance and repair and disposal. Although this tool was not meant for industrial designers, it was still important to note the system of criteria for evaluating products, as well as the software interface that the user interacts with.

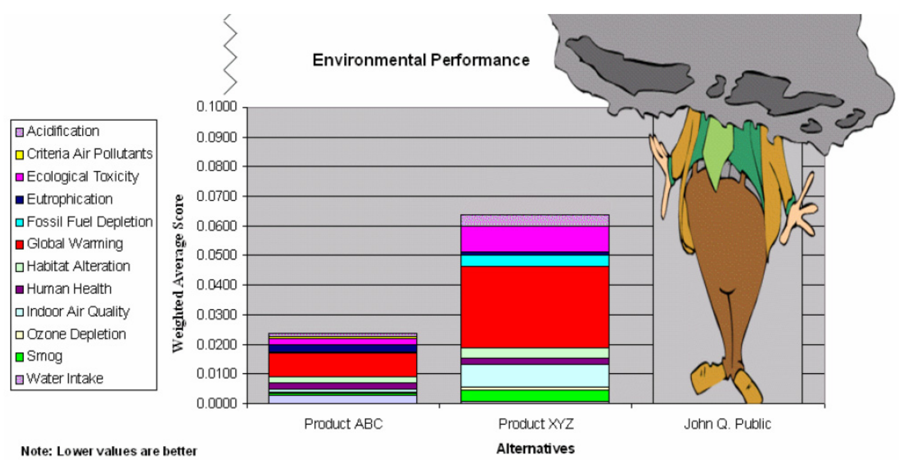

Figure 4: BEES System

As seen in Figure 4, the output of this software is similar to a nutrition label in that you have several categories of results and the user must come to their own conclusion as to whether or not to buy the food. In the BEES software, categories such as acidification, habitat alteration, ozone depletion, global warming and others are weighted according to EPA experts, which results in a final numeric score for the product. Each environmental impact category is determined and then compared to its share of annual per capita impact in the U.S. A product with a lower BEES score is a better product for the environment. For example, a product may contribute, on average, 0.0130 % of annual per capita U.S. environmental impacts, while another similar product may contribute a larger share, 0.0640 %. This is the ‘normalization’ phase of the BEES system because it is scaling the impacts according to a certain frame of reference.

BEES was developed by the U.S. Federal government as a systematic, rational technique for selecting environmentally friendly and cost-effective building supplies. The U.S. Government is the world’s largest consumer, purchasing more than $240 billion in products and services every year, therefore BEES sets standards and also has a heavy influence on vendors (Technology, 2007).

Although the BEES tool was developed by credible unbiased sources, it is not an ideal tool for product designers to use when trying to design ecologically friendly products. The tool evaluates the product comprehensively through its inputs and outputs and cost effectiveness, however it is not approached from a design standpoint. BEES is ideal for those wanting to make the best ecological product purchase, but it is not ideal for those trying to create the products. This system is similar to the LCA calculator in that it is strictly an evaluation tool and does not contain guidelines or suggestions for ecodesign strategies. The software succeeds in showing the product's environmental impacts individually, as well as the combined weighted versions which result in product's overall score. This was a feature that was an important consideration for the research project.

The second LCA tool evaluated was the Pharos Material Selection Tool. This visionary product labeling system is the collaborative project of the Healthy Building Network, The Center for Clean Products and Clean Technologies (CCPCT) at the University of Tennessee, Knoxville and the Cascadia Region Green Building Council.

Figure 5: Pharos Lens

The mission of the Pharos Project is to establish itself as the leading materials evaluation tool used by green building industries (Network, 2008). The members of the council feel that, with a plethora of new products and marketing claims in the building industry with various rating systems, there is no consensus on what constitutes a truly green product. This label is meant to put the knowledge and control back in the hands of the consumer by allowing them to make their own decision between various environmentally affective product attributes. The labeling scheme is comprised of two parts, the Pharos Lens, as shown in Figure 5 and the Pharos Label shown in Figure 6. The Lens is a visual indicator of the environmental impact information available from the Pharos Project. It evaluates the product under three categories: “Health + Pollution,” “Environment + Resources,” and “Social + Community.” The Lens is organized in a series of wedges that are each assigned a different social or environmental impact category. The Pharos Project team developed the wedge categories in order to format the information in a way which can be referenced easily by consumers. Not only is the information organized, but it is also easy to compare the environmental and social issues because all the information is visible at one time.

Although there were appropriate revisions, this circular format ultimately became the basis for the evaluation tool design for this research project. The design lends itself to quick environmental impact judgments in part due to the color scheme and quantity of wedges present. One of the thesis revisions involved resolving the misleading shapes and sizes of the wedges pieces. For example, the wedge pieces at the center of the circle are smaller in size compared to the wedge pieces around the outer edges, therefore the information may have an inaccurate representation.

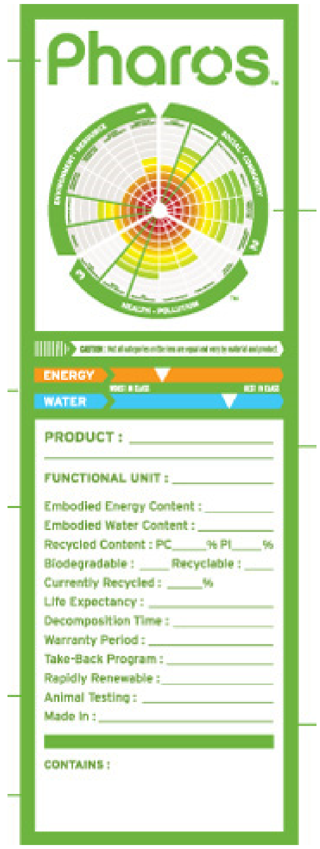

Figure 6: Pharos Label

In addition to the Lens, the Pharos Label also contains impact-related information about the product's inputs and pre-consumer phases of the life cycle. The label gives a brief history of some of the product's characteristics including life expectancy, warranty period, animal testing, and energy content. Some of the crucial information that was excluded is information about the use of the product including energy consumption or conservation, and also information about the end of life cycle including recycling programs or product take-back programs.

The next LCA tool analyzed was the ECO-it software developed by PRé Consultants, a Netherlands based design firm. ECO-it allows designers to model a product and its life cycle then calculates the environmental load. It compares various stages of the product life and like Pharos and BEES, this software allows the user to determine which life cycle stages affect the environment the most. This tool is distinct from the Pharos and BEES tools in that it was developed by designers for designers to use.

ECO-it works by assigning scores, or Eco-indicators that express the seriousness of the environmental load of a design decision, process or material. First, the designer must enter information about the product's life cycle, next they enter information about inputs and outputs of the product including the materials and process. After entering information about life cycle and production, next the designer enters information about the product's use which includes energy and transportation. Lastly the designer enters information about disposal and end of life of the product including a typical waste scenario. After entering all the data the designer receives immediate feedback on the environmental load of the product. The results are displayed as a red (positive value) or yellow (negative value) to illustrate the environmental impacts of the life cycle stages. According to how accurate the data is, the results could either be a rough estimate or fairly accurate. Assumptions may lead to inaccuracies and misleading environmental loads. When comparing two or more products, for example, the designer must enter the most accurate data in order to get meaningful results.

This tool, like most LCA tools is strictly for evaluation purposes, putting the burden of discovering eco-design alternatives on the designer. ECO-it can only be applied at the end of a concept or product and is not a practical tool for concept generation or for making crucial design decisions. The tool and the results are, however, both very accessible as the tool costs USD $ 140.92 and can be downloaded immediately.

2.2.3 Product Certifications

The concept of environmental product certifications is a fairly new one; however there are several that exist today. Certifications such as the McDonough Braungart Design Chemistry (MBDC) Cradle to Cradle certification are for-profit independent agencies that analyze products and processes to determine whether or not they can be worthy of an eco-label. Other non-profit organizations such as the U.S. Environmental Protection Agency (EPA) and Green Seal offer certifications for products as well as manufacturers and set industry standards for environmental performance. Reviewing the processes by which the products and business were certified and by what criteria they were judged was important for this research, especially for developing the evaluation tool.

The first certification service reviewed was the MBDC Cradle to Cradle certification. MBDC is a design firm founded in 1995 by William McDonough and Dr. Michael Braungart to help promote what they call the “next industrial revolution” (Braungart, 2008). Their concept of a revised design paradigm is referred to as Cradle to Cradle Design and focuses on designing products and systems based on patterns found in nature and eliminating the concept of waste entirely. This strategy optimizes materials and operates in a closed system, recycling material from one product life cycle stage to the next. Essentially they abandon conventional theories of conservation and focus on re-use.

The Cradle to Cradle Protocol uses a LCA approach of assessing materials used in products as well as production processes. Materials are first inventoried, similar to

LCA methods and then evaluated according to their characteristics and placed into one of four categories (Green, Yellow, Orange, or Red) based on their human health and environmental impact. Next, chemical analysis's are performed and materials, that are identified as Red are compared to replacement materials referred to as Green materials to see if there is an opportunity for harmful chemicals to be replaced by non-harmful ones. In addition to products, MBDC also evaluates and optimizes manufacturing processes based on safety, materials use, and energy consumption. Other opportunities for optimization are examined in the company's supply chain system as well.

MBDC markets itself as a business tool promising to incorporate cost reduction, design for lifetime costumers, risk management and competitive advantage. Although they are a design firm, their services are not targeted towards product designers specifically, but towards management and businesses as a whole. Often the strategies for improvement go way beyond the realm of responsibilities of the designer and must be implemented on a corporate level.

The next certification analyzed was the Green Seal Certification. Founded in 1989, Green Seal is an independent nonprofit organization 'dedicated to safeguarding the environment and transforming the marketplace by promoting the manufacture, purchase and use of environmentally responsible products and services' (Seal, 2008). The organization uses science-based environmental certification standards to help manufacturers, purchasers and end users make responsible choices that will positively impact the environment. Their services are especially utilized by large institutional purchasers including government agencies, universities and lodging and architectural building industries. Green Seal is just as active in helping advise these institutions in their eco-friendly purchasing efforts as they are in evaluating and certifying products. The certification process operates with a life-cycle approach by evaluating the material extraction, manufacturing, use and the end life of the product. In order to assure accuracy, products can only be certified after life-cycle analysis, scientific testing procedures and an on-site plant visit have been conducted. Similar to the MBDC certification, the Green Seal certification is a business tool for ecodesign credibility. This service is outside the realm of the designer and incorporates changes on a corporate level. The service prices are determined according to the annual revenue of the company requesting the certification. Companies with annual revenues in excess of $500 million must pay $9,500 while companies with annual revenues less than $5 million pay $3,500. Even if this was a tool specifically for designers, it would be unlikely that a business would be able to justifying paying that amount to have all their products certified.

The next certification system researched was the effort of the U.S. Environmental Protection Agency. The EPA educates consumers and businesses on various environmental regulations as well as educational resources. Their information is categorized under seven main environmental impact categories: Water, Air, Climate, Waste and Pollution, Green Living, Human Health and Ecosystems (Agency, 2008b). The organization has two main product certification categories, WaterSense and ENERGY STAR. WaterSense is a partnership program that helps consumers choose water-efficient products. Business and organizations can partner with WaterSense to get their products certified. First they must enter into a partnership agreement with the

Figure 7: EPA Water Sense Logo

EPA and sign a draft specification for a product they manufacture or sell under a private label. Under the agreement, the manufacturer gets twelve months to obtain their certification of a product and prove that it conforms to the WaterSense specifications for water efficiency. The WaterSense program also has a posted listing of licensed certifying bodies that are currently accredited. Once certified, the manufacturer or product may display the WaterSense logo, as seen in Figure 7.

In addition to WaterSense, the EPA also sponsors a joint program with the U.S. Department of Energy called ENERGY STAR. This program helps save money and protects the environment by helping consumers choose energy efficient products and practices. In addition to evaluating products, EPA provides an innovative energy performance rating system that also recognizes top performing buildings, both commercial and residential, with the ENERGY STAR certification (Agency, 2008a).

Figure 8: ENERGY STAR Logo

Similar to the WaterSense program, ENERGY STAR also contains a database of all the products that have met their energy efficiency standards and received certification and the product or manufacturer receives permission to display the ENERGY STAR logo, as seen in Figure 8. There are several categories of products certified including appliances, heating and cooling, lighting, office products and water heaters. By displaying the ENERGY STAR logo consumers have the ability to make purchasing choices that will save them money on energy bills as well as allowing them to make the best choice for the welfare of the environment.

Like the WaterSense program, manufacturers that request an energy efficient certification must first register to the program and then validate that their products meet the ENERGY STAR specifications. Once their products have been approved they are given permission to display the program’s logo and they will be entered into the database.

The main objectives of these EPA programs are to help consumers make environmentally responsible purchasing decisions. Although the programs are not developed for designers, it is possible that they can use their strict certification specifications to inform their design decisions. The act of achieving the specifications may be difficult for some, especially those not familiar with ecodesign principals. Concrete design strategies may be more relevant for these individuals.

2.3 Existing Environmental Standards and Tools in Other Industries

In other industries outside of product design there are organizations that help promote environmental awareness and responsibility. Within the building industry, for example, there are several associations that offer resources to professionals as well as consumers. In the forest industry, as well, there are also organizations that govern the manufacturing of wood products and promote responsible forestry. Similarities between the industries and their guidelines for environmental protection helped shape the guidelines and format for this project.

The U.S. Green Building Council (USGBC) is a non-profit organization committed to promoting sustainable building practices (U. S. G. B. Council, 2008). The USGBC is a national organization with local and regional chapters to assist building owners, end-users, real estate developers, architects, designers, contractors and government agencies in developing high efficiency buildings that have a minimal impact on the environmental. The goal of the organization is to transform the way buildings and communities are designed, built and operated, enabling them to be healthy for the environment and the occupants as well as socially responsible.

The USGBC is to the building industry as IDSA's Ecodesign is to the industrial design industry. There are several programs operated by the USGBC that help carry out their mission of promoting sustainable buildings. The LEED® (Leadership in Energy and Environmental Design) Green Building Rating System, which is a voluntary, third party national rating system for distinguishing and developing high-performance, sustainable buildings is USGBC's most widely adopted program. The system addresses all building types including new construction, existing buildings, operations and maintenance, commercial interiors, core and shell, schools, retail, healthcare, homes, and neighborhood development. Similar to LCA systems, the LEED system analyzes buildings from site development up until operation with occupants.

LEED operates based on a points system. Points can be earned when the building or neighborhood satisfies the requirements or suggestions for the key areas of impact: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process. For each environmental or health impact category there is a minimal number of points that must be earned to receive the credit for that particular category. Each category's points must be earned to achieve the overall LEED certification. For example, a building that is water efficient and energy efficient alone will not achieve LEED certification. Instead, the building must meet the environmental standards in all of the categories to achieve certification. Although the builder and owner has the choice to choose between possible points within each category, some are prerequisites for LEED accreditation. There are 69 possible points in the LEED system and different levels of classification. To achieve LEED certification the building must be awarded 26–32 points, 33–38 points for silver, 39–51 points for gold and 52–69 points for platinum.

LEED was developed through an open, consensus based process led by LEED committees. The volunteer committee members are divided into groups based on their area of expertise in the building and construction industry. They strive to incorporate a balanced and transparent committee structure and technical advisory group that ensures scientific accuracy, as well as opportunities for stakeholder comments, reviews and appeals.

Although LEED works to maintain an unbiased, fair evaluation system, there are several critics who question their methods. In a Southern Forest Products Association newsletter from 2003, the organization criticized LEED for 'political biases and agendas that cannot be ignored.' (Association, 2003) They object to LEED's classification of acceptable lumber as only lumber that has been certified by the Forest Stewardship Council (FSC) because the council only certifies approximately 2% of North American wood products. A large portion of the remaining lumber may actually be certified through other programs such as the Sustainable Forestry Initiative and American Tree Farm System, however it is not accepted by LEED. Due to this system architects and designers may be inclined to use nonrenewable alternatives such as steel and concrete. Although LEED is committed to promoting sustainable buildings, the fact that they are selective in their endorsements to other environmental organizations and certifications has certainly made them a target for criticism. Perhaps this may ultimately be the best format for building design evaluation, but for industrial design, when the results are focused on the life of one product, the need for a complex system with points and credits may be in excess. Instead of a system that distinguishes one product from another in the market place, the guidelines of this research will be used mainly within the design team as a personal evaluation tool or reflection tool for designers.

As mentioned earlier, the Forest Stewardship Council (FSC) is an international organization dedicated to promoting responsible forestry. The FSC was formed in 1993 driven in part by the lack of an intergovernmental global forest initiative. Loggers, foresters, environmentalists and sociologists came together to answer the question, 'what is sustainable forestry?' and how to promote it (F. S. Council). Much like industrial design, people within the forestry industry witnessed the environmental and social effects of their industry including; habitat destruction, water pollution, and displacement of indigenous peoples and wildlife.

Since 1993 the organization has been setting industry standards particular to each geographical location because sustainable forestry varies from region to region. In the U.S. regional standards were developed in 1997 by working groups of volunteers. By 2001 the regions were required to 'harmonize' their standards with a new set of national standards and principals. This was an effort to help achieve consistency in the FSC's efforts. The FSC standards for forest management have been applied in over 57 countries, and the certification is one program which has improved the practice of forestry. FSC has developed a universal set of Principles and Criteria for forest management that are applicable to all FSC-certified forests throughout the world. There are 10 Principles and 57 Criteria that address legal issues, indigenous rights, labor rights, multiple benefits, and environmental impacts surrounding forest management. The guiding principles include conserving biological diversity and the integrity of the forest, operating efficiently, upholding workers rights and creating positive community relations.

The FSC has succeeded in organizing a global task force enforced with local standards and processes. In order to achieve consistency in the FSC certification, the organization has developed their 10 universal principals. Since the social and environmental needs of forests can vary dramatically from one region to the next there is a need for more in-depth principals customized to separate regions. The global scale of the FSC is outside the realm of this project, however, their philosophy could be applied to sustainable design organizations. Like other guidelines and evaluation tools, there are broad principles that are necessary regardless of the geographic location or particular situation, and then there are also more specific principles that may only apply to some circumstances. For example, all products should be designed efficiently to use the least amount of non-renewable resources; however, designing a product to be water efficient may be mandatory in drought areas and optional in others.

CHAPTER 3

METHODS

3.1 Background Research

The main purpose of the initial background research was to determine what information would be included in the guidelines and product evaluation tool. To successfully develop this tool for designers it was important to include relevant design strategies that designers had control over, as well as ecodesign principals that would positively impact the environment.

3.1.1 Determining the Data to be Included in the Guidelines and Evaluation Tool

The end goal of this research project was to develop guidelines as well as evaluation parameters to facilitate and encourage ecodesign decisions within the industrial design industry. A matrix, shown in Figure 9, was developed to compare the various design tools, LCA tools and product certification systems. The goal of this project is highlighted by a green circle with a dashed outline. As represented in the matrix, the Okala guidelines were the most similar to the end goal of this project, however they were not designed specifically for practicing designers, but rather those who are learning or teaching ecodesign as a curriculum. Also represented in the matrix was the realization that most of the tools were either guidelines *or* evaluation tools, and rarely did any of the tools incorporate both. This project has a similar model to an educational course in that the designer receives the guidelines or information and then they are tested to see if they were able to successfully apply the strategies. If there was only an evaluation tool, then the designer may not know how to execute the ecodesign principals. If the designer only had the guidelines, then they may not be able to evaluate whether or not they were successful in implementing their ecodesign decisions.

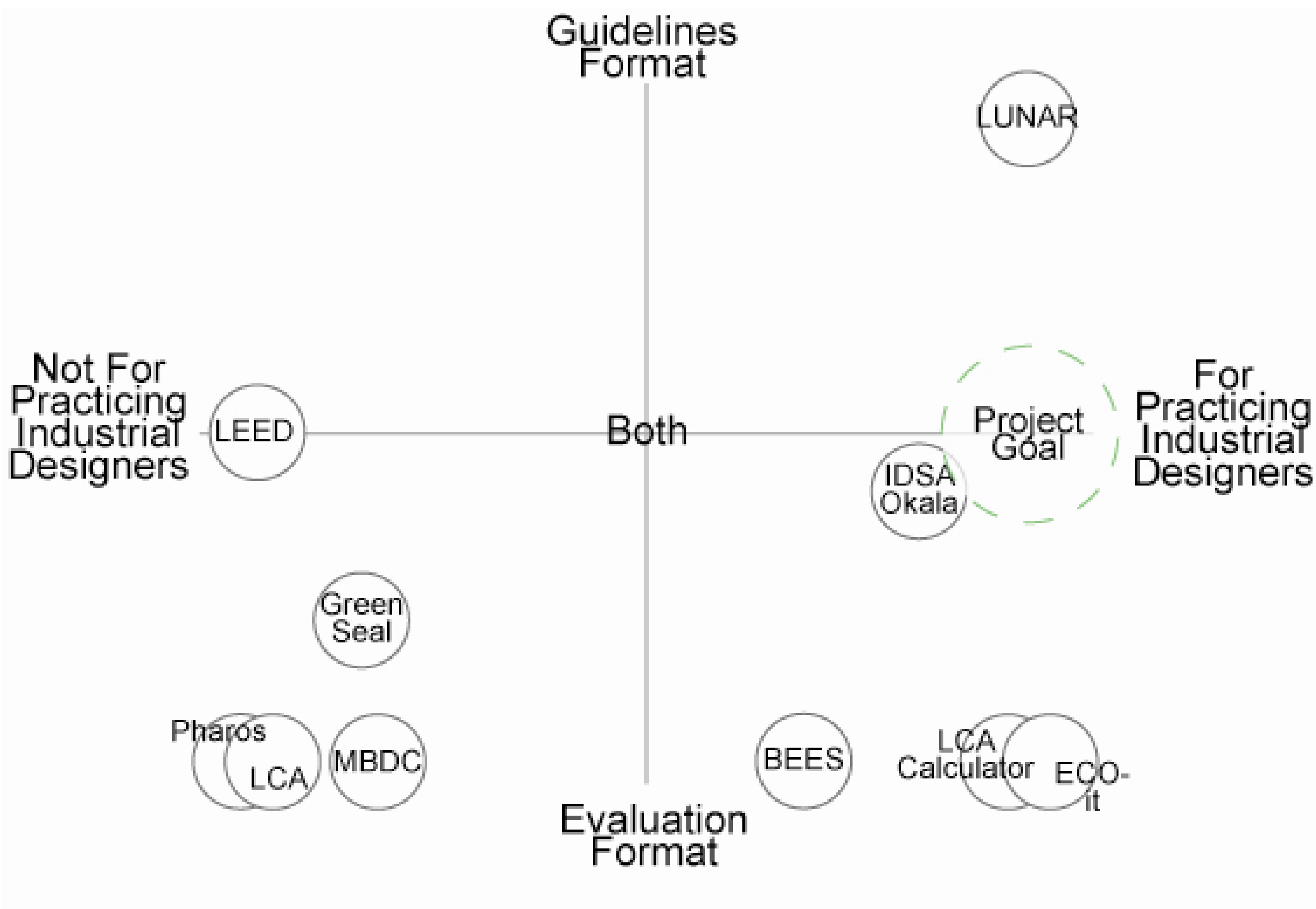

Figure 9: Comparison Matrix

At the beginning stages of this research five practicing designers working in a corporate design setting were asked through an interview about what design strategies they had control over. It was found that most designers had control over design decisions determining the actual concept of the design, the form and function of the design and typically material choices, however they did not necessarily have control over where the materials were sourced from. The range of designer control differs from project to project, however, this information matched what the IDSA found in their 2003 survey (referenced earlier) of electronics designers. The fifty-two designers who responded to the survey stated that they were able to influence, 'form, color, texture' and 'finish type' as the top two responses (Davis, 2004). It was important to the accuracy of the product evaluation tool to only incorporate design decisions that designers could impact or else product characteristics that were out of their control may negatively impact their evaluation score.

Next, the ecodesign strategies and environmental design principles had to be compiled and organized according to which stages in the product life they were relevant. For example, at the end of the product life, some principles such as 'conserve material resources' were not applicable.

3.1.2 Research of Existing Environmental Guidelines, Tools, and Resources

It was apparent after only a short period of initial research and literature review that there were endless sources of information regarding sustainability, eco-efficiency and ecodesign strategies. To organize and compile all the data, the principles were recorded in a spreadsheet format. Relationships between the principles began forming and they were grouped according to their underlying concept. *S*oon more than a hundred were grouped and categorized according to the seven Okala ecodesign strategies; innovation, low-impact materials, optimized manufacturing, efficient distribution, low-impact use, optimized product lifetime and optimized end-of-life. Through this grouping process it was apparent that there were several environmental guidelines from various sources that could be eliminated because they were similar or redundant. For example, when guidelines were being compiled from various sources, one environmental principle suggested extending the product life, while another similar principle suggested optimizing the product life. In these instances the principles were combined into one. This strategy allowed all the principles and ecodesign strategies to be considered and categorized for possible incorporation in the final version of the guidelines.

3.1.3 Determining the Product Life Cycle Stages and Environmental Principles

At an early stage in the literature review it was discovered that some of the widely recognized design tools presented the environmental principles in comparison to the product life cycle stages. With this method the designers can see that the product starts impacting the environment long before it reaches the consumer and also keeps impacting the environment long after its useful life ends. It is also easy to see all the areas of opportunity for improvement throughout the life of the product.

In determining the life cycle stages of the product, it was important to compare various existing ecodesign tools as well as literature about ecodesign and then customize the stages to be specific for the design industry and the application of this tool. Victor Papanek described the phases of product life that have the ability to impact the environment in his book *The Green Imperative*. Okala's life cycle stages, Papanek's phases as well as the LCA Calculator's phases are compared in Figure 10.

Source	**Papanek**	**LCA Calculator**	**Okala**
Life Cycle Phases	Choice of Materials	Extraction and Manufacture	Raw Material Extraction
			Material Processing
	Manufacturing Process		Component Manufacturing
	Packaging the Product		Assembly and Packaging
	The Finished Product		
	Transporting the Product	Transport	Distribution and Purchase
		Use	Installation and Use
			Maintenance and Up-grading
	Waste	Disposal	Incineration or Landfilling, or Recycling, Reuse

Figure 10: Comparison of Life Cycle Phases

It was determined through previous interviews and by referencing an IDSA survey about designer influence that designers did not have control over material extraction. Although it is justifiably a life cycle phase of the product, it is not a life cycle phase that the majority of designers can control; therefore it was left out of the final tool. Instead, the material choice portion of the evaluation tool would weigh into effect how the materials were sourced. Designers did have control over concept design, which is the form and function of the product as well as detail design which are material choices and color choices and as result, they were the first two phases included in the tool (See

Figure 11). The next four life cycle phases “manufacturing,” “packaging, storage and distribution,” “use and maintenance,” and “disposal, recovery, recycle” were developed through combining and simplifying the phases of Papanek, LCA Calculator and Okala.

As mentioned earlier, the environmental principles were arranged in a spreadsheet and grouped according to their underlying concept. It was found that all the principles could be placed within the six following processes: use of benign materials, conservation of resources, efficient manufacturing, efficient distribution, extend product life, and facilitate reuse, reclaim, recycle.

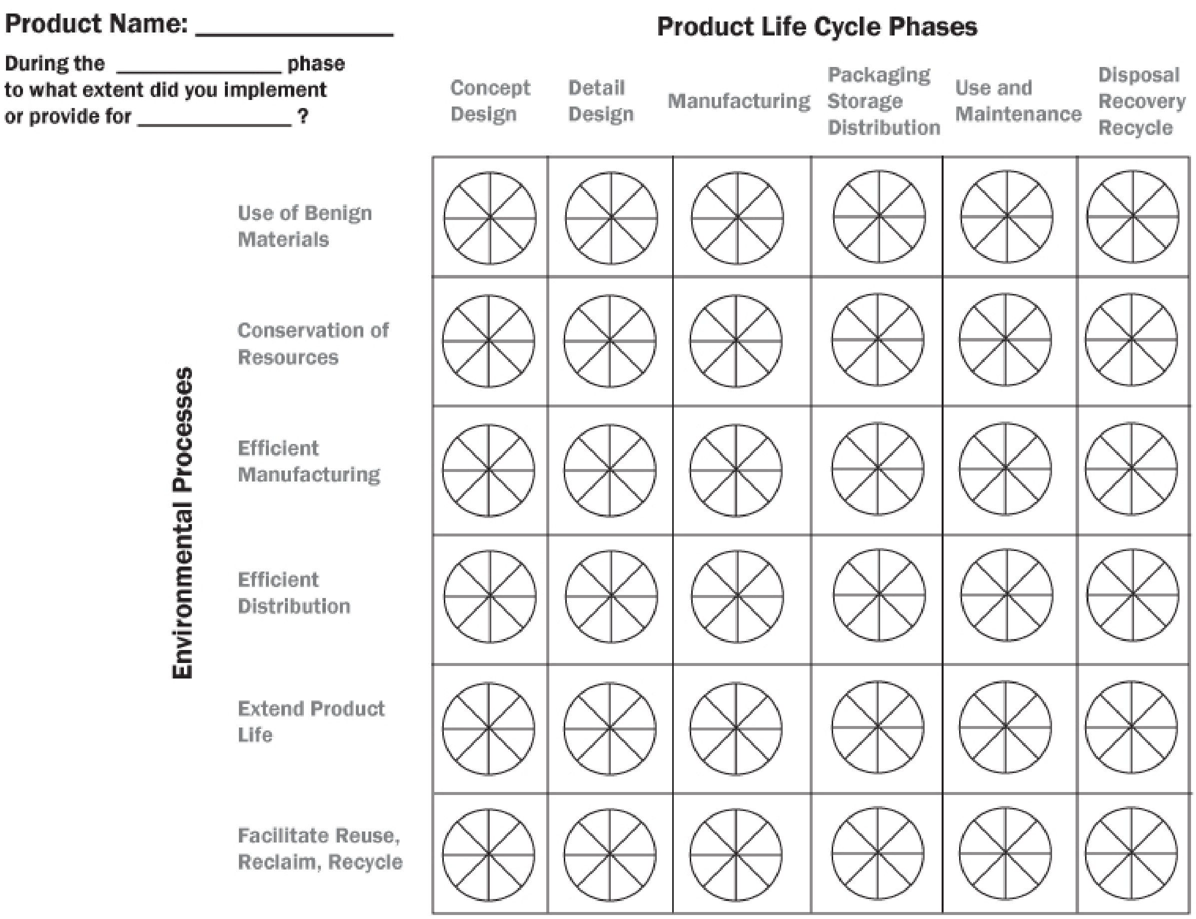

Figure 11: Phases and Processes Chart Version 1

3.2 Develop the Evaluation Tool

To be the most effective in helping facilitate environmentally friendly design choices, there were several criteria the tool had to adhere to. First, and most importantly the tool had to fit seamlessly within the designer's process of product development without involving significant changes to their design processes. This tool had to avoid being considered a burden or a distraction by designers, or else it would never be adopted. Also, the tool would ideally be used for any phase of product design including concept generation or reflection on finished products. In addition to it blending in to the designer's routine, the tool had to also be easy to understand with a minimal learning curve associated with the implementation. Second, the tool had to be able to be applied by the designer or design team independently, without the cooperation or involvement from additional people outside the company or third parties. When tackling the challenges of ecodesign, it may be difficult to get other parties onboard to participate in these revised product development routines. Third, the tool had to be easy to access. This includes proximity and availability to the product designer, as well as any financial fees associated with the tool. If copies of the tool are not within reach (both physically and financially) of the designer, then there will be reluctance to incorporate the tool at all. Lastly, the tool had to be affective in educating the designers about ecodesign principals as well as the environmental consequences of their design decisions.

Designers have specific strategies and processes by which they create products that are unlike other professions. For example, engineers typically work according to a set of specifications and objectives while designers design with guidelines, user research, and their own personal intuition. The final format of these guidelines and evaluation tool challenged to embody this very philosophy of giving the designers options and not requirements.

3.2.1 Design Evaluation Tool Format

The evaluation tool went through numerous rounds of refinement. Its first form, seen in Figure 11, asked the designers the question, ‘During the (Product Life Cycle Phase) to what extent did you implement or provide for (Environmental Process)?’ Since designers work in a visual industry it was important that the results have a visual indication, therefore the answers to their questions were to be represented by shading in the circular segments. This concept was later abandoned because the circular segments seemed to give a quantitative result to a qualitative question. To solve this problem, a new strategy was developed using a shaded bar to represent the answer as opposed to a circle with segments (See Figure 12). The first revision also incorporated a ‘Not Considered’ (NC) and ‘Not Applicable’ (NA) choice for the designer. The ‘NC’ choice would be used when the environmental processes was not incorporated during the particular life cycle phase. The ‘NC’ option represented that the environmental process truly was not incorporated in the design and not that the designer simply failed to answer the question or accidently skipped it. For example, there may have been opportunities to use a biodegradable or recyclable material for the product, but it was not implemented in the final design. The ‘NA’ option would be used in circumstances in which the designer could not answer the question due to inadequate information or uncertainty, or if the statement simply did not apply for the particular product. For example, if the product did not have any packaging then the designer would be unable to answer whether or not they used benign materials in the packaging. Another revision to the tool was the concept of adding notes so the designer could justify or explain their reason for each rating. This may be important data for designers when comparing multiple products and also for referencing designs that were evaluated in the past.

The disadvantages of this tool, which eventually led to the final revision, were that the results were presented graphically but not quantitatively. When comparing multiple product evaluations, which was an objective of the tool, the only way for judging the designs was through a comparison of the shaded bars. There was a need for visual graphic results, but also a final score or numerical result for accurate comparison.

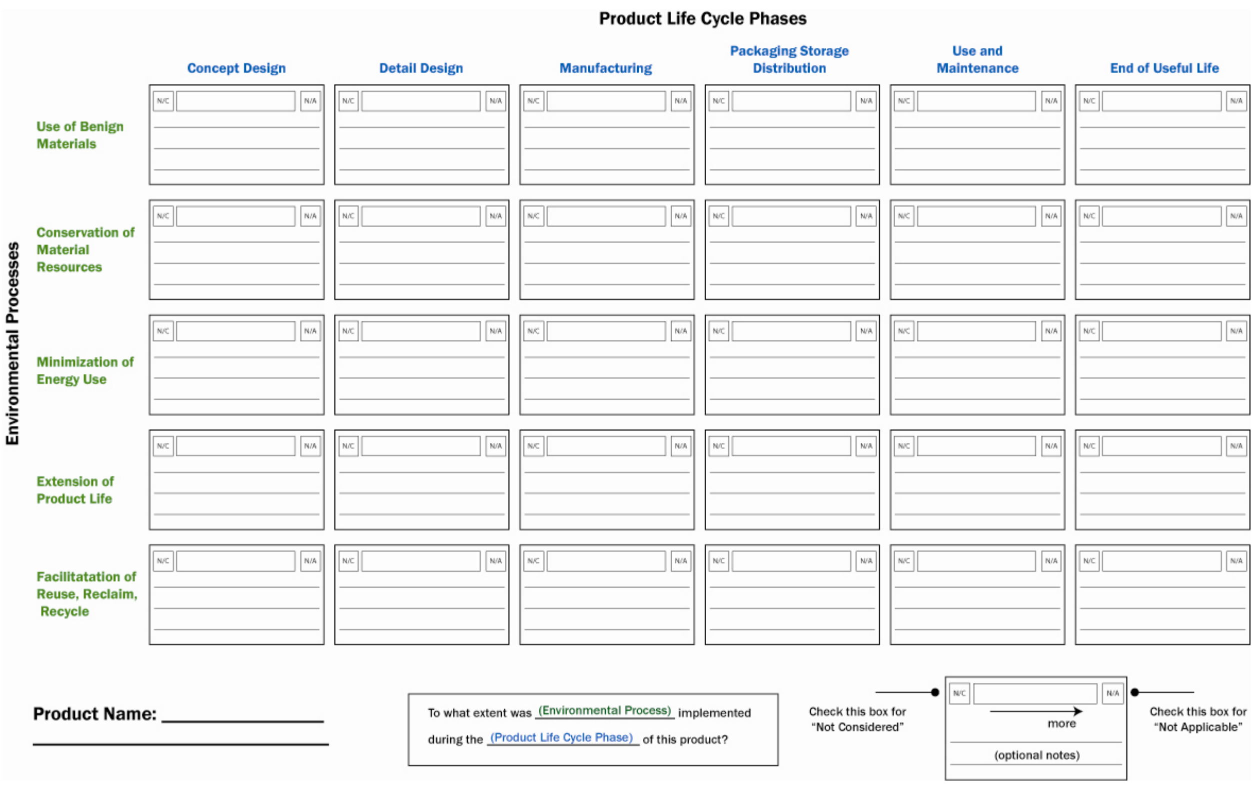

Figure 12: Phases and Processes Chart Version 2

Throughout the revision processes numerous pilot studies were conducted by the researcher with products ranging from floor lamps to household cleaners. Not all the information could be answered accurately due to insufficient information regarding the manufacturing and distribution processes of the particular products; however, the exercise revealed flaws in the usability of the tool.

3.2.2 Pilot Test: Practicing Designers and Eco-Design Experts

After the first revision of the tool (Figure 12) and initial pilot studies with the researcher, it was necessary to pilot test the tool with individuals who had not been present during the development process. For this phase three practicing industrial designers working in corporate design were asked to review the tool and test the tool. Out of these three designers, one was considered an ecodesign expert, having written a thesis on ecodesign, and developed a biodiesel lawnmower. The other two designers had no ecodesign experience or education, so they were considered novices. In addition to the three practicing designers another ecodesign expert, currently a practicing professor of industrial design, was given the tool for feedback.   All of the designers received the tool along with instructions and definitions of the processes and principles. For the three practicing designers, the researcher was present to answer questions and describe how to use the tool, but in the case of the ecodesign professor he received only the instructions and description of the tool. The results from these pilot tests indicated that there was some confusion about the terms especially for the designers who had no ecodesign experience. For example, the participants questioned the life cycle phases and were unclear as to what distinguished ‘Detail Design’ from ‘Concept Design.’ Participants were also reluctant to shade the bar because for some questions they did not have a basis for judgment. For example, one of the questions may have asked “During the (Manufacturing Phase) to what extent did you implement or provide for (Minimization of Energy Use)?” and in this instance the designer may not have a frame of reference in which to compare the energy use. Instead of asking the designer to rate their product by shading a bar, the tool was refined to have check boxes as seen in Figure 13. The question the designers were asked was changed to, ‘The (Environmental Process) was implemented during the (Product Life Cycle Phase) of this product.’ The check box options were, ‘Not Applicable’ (N/A), ‘Strongly Disagree’ (SD), ‘Neutral’ (N), ‘Agree’ (A), ‘Strongly Agree’ (SA). With this revision designers could answer specific questions with answers, instead of arbitrarily shading a box. The answers would be scored according to a rating scheme and the final total could be

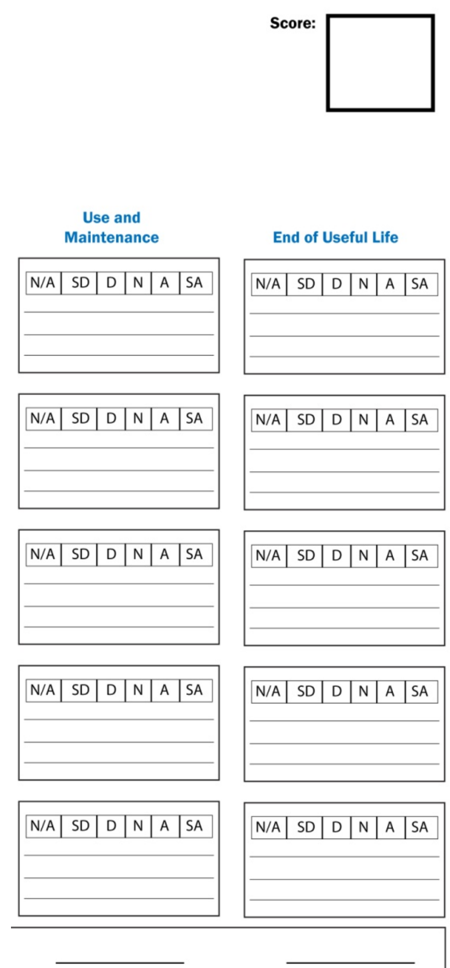

Figure 13: Phases and Processes Chart Version 3

tallied at the bottom of each row. Although this refinement gave a quantifiable result for accurate product comparison, it eliminated the visual feedback.

Another key concern with the tool was the ‘concept design’ and ‘detail design’ phases of the lifecycle. Although these were legitimate phases of the life cycle, especially in the design field, these phases do not have a direct impact on the environment. Essentially the product does not start impacting the environment until its materials are extracted and the product is actually manufactured. For example, if during the concept design phase the designer chooses to incorporate an energy efficient motor, then the design decision starts impacting the environment at the time of use, not at concept design. To improve the simplicity and accuracy of the tool, it was revised to include only the four life cycle phases that impact the environment; ‘Manufacturing,’ ‘Packaging, Storage Distribution,” “Use and Maintenance,’ and ‘End of Useful Life.’

3.3 Develop Design Guidelines and Refine Evaluation Tool

After several revisions of the evaluation tool the next stage was to develop guidelines so that novice ecodesigners could gain an understanding of how to implement ecodesign strategies. To develop the guidelines, the original spreadsheet of environmental principles was arranged and formatted into a web application. The guidelines were organized by life cycle phases and within each phase were the environment principles and design strategies which could be applied. As shown in Figure 14, not all environmental principles could be applied at every life cycle phase. For example, during the end of useful life phase it was impossible to incorporate principles regarding the use of benign materials, because at this point the product had already been manufactured and used.

Life Cycle Phases	**Manufacturing**	**Packaging, Storage, Distribution**	**Use and Maintenance**	**End of Useful Life**
Environmental Principles	Use Benign Materials	Use Benign Materials	Use Benign Materials	X
	Conserve Material Resources	Conserve Material Resources	Conserve Material Resources	X
	Minimize Energy Use	Minimize Energy Use	Minimize Energy Use	X
	Extend Product Life	X	Extend Product Life	Extend Product Life
	Facilitate Re-use, Reclaim, Recycle	Facilitate Re-use, Reclaim, Recycle	Facilitate Re-use, Reclaim, Recycle	Facilitate Re-use, Reclaim, Recycle

Figure 14: Life Cycle Phases vs. Environmental Principles

The guidelines were designed as a web application for optimal accessibility. An icon was developed for each environmental principle category. This helped give the principles an identity and allow them to be easily recognizable by the user. The layout of the application was designed to resemble a book with tabs. Each life cycle phase had its own tab and beneath each tab was a menu with the underlying environmental principles that were relevant for that life cycle phase, seen in Figure 15. Once the designer picked an environmental principle category they were directed to a page that gave design strategies for achieving the environmental principle during the specific life cycle phase as seen in Figure 16.

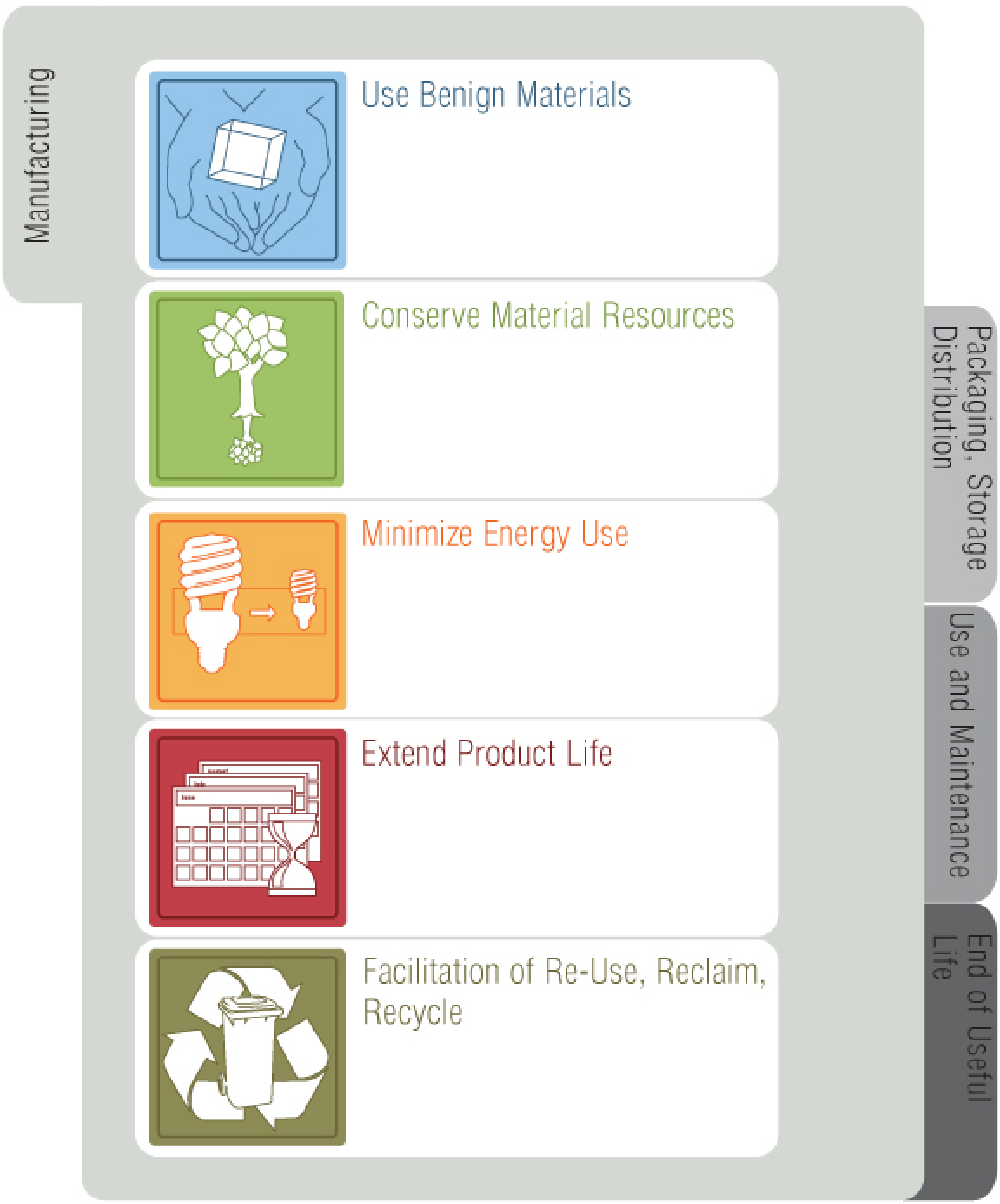

Figure 15: Guidelines Web Application: Manufacturing Menu

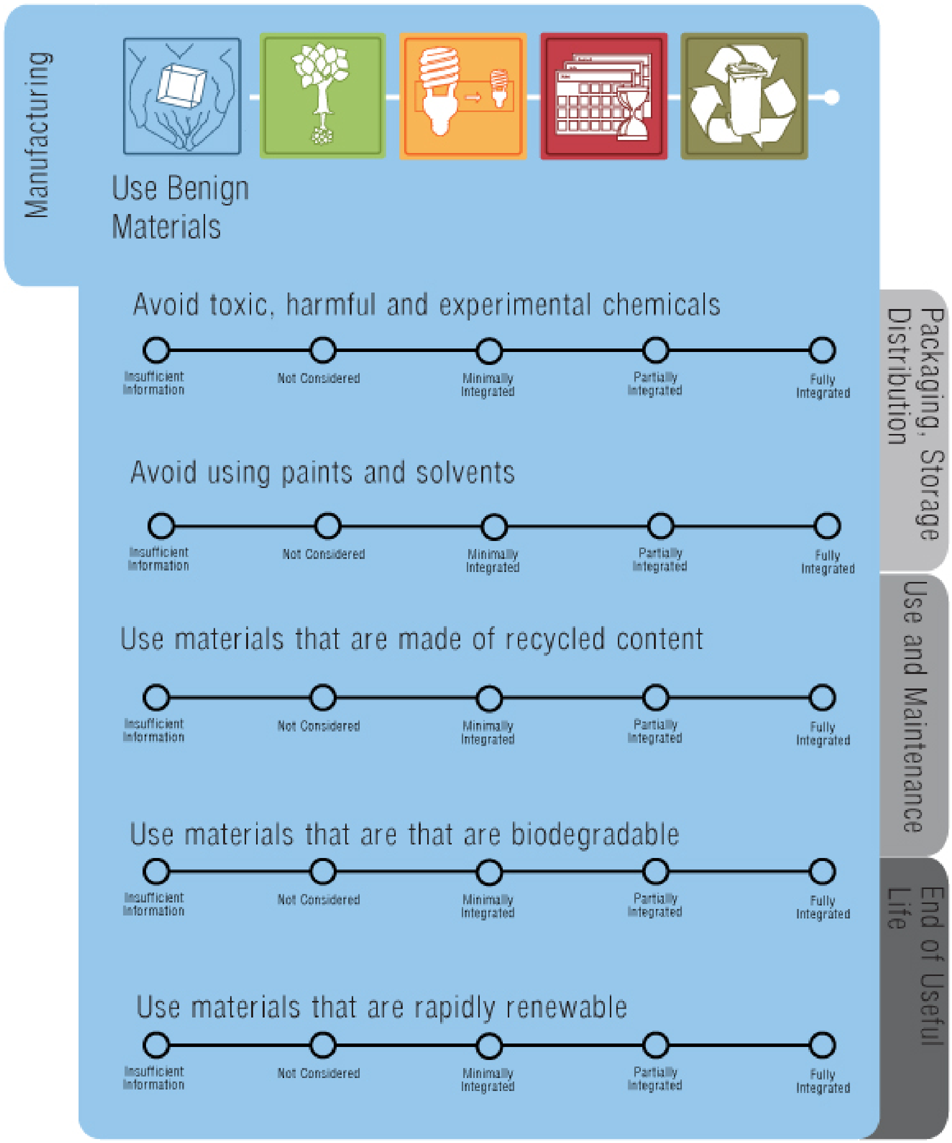

Figure 16: Guidelines Web Application: Manufacturing, Benign Materials

These design strategy statements, or environmental principles could be used for brainstorming exercises during product development, or they could be use for evaluation purposes when the design process was complete. To evaluate the product, the designer would record to what extent they integrated the design strategy or principal. There were five bubbles the designers could choose from to answer the statement; 'Insufficient Information,' 'Not Considered,' 'Minimally Integrated,' 'Partially Integrated,' and 'Fully Integrated.' These answer choices were a revision of the previous choices ('Not Applicable,' 'Strongly Disagree,' 'Neutral,' 'Agree,' and 'Strongly Agree') from Figure 13. With the new rating system the designer did not have to answer an opinion based question, but rather a design driven question. This may provide more accurate ratings that are less subjective.

After developing the guidelines in the web application format the evaluation tool was reconsidered. There no longer needed to be a separate evaluation tool with questions, because the guidelines essentially became the rating system. Instead, a

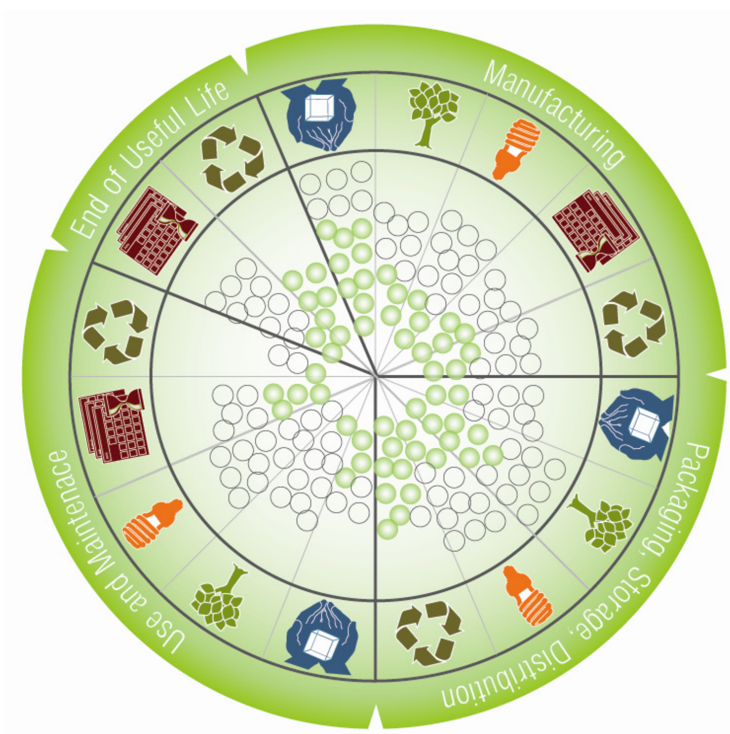

Figure 17: Web-Based Product Evaluation Tool

simple, cohesive output for the rating data was used so the designer could quickly determine whether or not the product design was environmentally benign, or what areas of the product life needed to be improved. Since the guidelines were in web based format, it was most appropriate to also incorporate the evaluation tool into this system. After answering the guidelines statements the designer could submit the data and the system would automatically generate their product rating.

To develop a scoring system, the bubbles were associated with a numerical value. ‘Insufficient Information’ and ‘Not Considered’ were zero points, ‘Minimally Integrated’ was one point, ‘Partially Integrated’ was two points and ‘Fully Integrated’ was three points. The graphic layout of the tool was inspired by the Pharos Lens which was referenced earlier (See Figure 5). The structure of the tool was similar to previous iterations where the data was organized by product life cycle phases, and under each phase were the environmental principals (See Figure 17). For each possible point, there was a bubble on the evaluation tool that would be shaded. For example, if the designer answered ‘Partially Integrated’ for one of the statements, then according to the rating system two bubbles would be shaded green in the tool. For each statement there was a maximum of three points that could be awarded. As seen in Figure 17, some of the environmental principles had fewer design strategies than others; therefore the different wedge portions had varying numbers of bubbles. The total score for the product would be the number of total bubbles that were shaded. The shaded bubbles allowed the designer to quickly make a visual judgment or comparison of products, and the final score gave a quantitative result for comparison between multiple products. The greener the evaluation diagram was, the more environmentally friendly the product design.

3.4 Test the Guidelines and Evaluation Tool with Students

The next phase of the research was the actual testing of the tool. The tool was tested by industrial design graduate students for usability as well as its effectiveness in assisting designers in implementing ecodesign decisions. Although the tool was developed for practicing industrial designers, the 16 graduate student designers had realistic design scenarios and constraints similar to those practicing in the industry, so they were appropriate candidates for the research. Their particular studio class was chosen for the research because the curriculum had am emphasis on sustainability and efficient product design.

The design project that was tested was a two week long group project with two students in each group. They were required to consider all phases of the product's life as part of their assignment. Prior to the concept generation phase and design phase the researcher presented eco-design principles and instructions for using the guidelines and evaluation tool to the participating class. After the two week project was completed and the students had completed their assignments the researcher came back to the studio class and interviewed the students in their groups to discuss the guidelines, evaluation tool and their finished products.

The act of using the guidelines to develop concepts was voluntary; therefore some students chose to use the guidelines and some choose to disregard them. All the students, however were required to evaluate their projects according to the guidelines and evaluation tool.

Similar to practicing designers in the industry, there were varying levels of ecodesign experience and knowledge throughout the students in the class. Some of the students were passionate about ecodesign while others were novices unfamiliar with the concept. At the start of their Masters Studio design project they were given the web address for the prototype guidelines, a copy of the product evaluation tool and a brief description of how to use the tool. They also received instructions on how to manually score their designs with the evaluation tool, shown in Appendix A, Figure 26, because at this phase the guidelines were a prototype and the answer choices were not dynamic.

CHAPTER 4

RESULTS

4.1 Test Feedback

At the completion of their two week project, the students were interviewed in their project groups by the researcher about the usability of the guidelines and evaluation tool. The questions can be viewed in Appendix A, Figure 24. They were asked about navigating the tool as well as the content and overall design of the tool. In addition to the initial interview session there was a separate questionnaire distributed by the professor of the class two weeks after the initial interview. This questionnaire, as seen in Appendix A, Figure 25, was meant to gain meaningful feedback from the students about the effectiveness of the tools as well as whether or not the tools influenced their designs. The professor distributed the questionnaire without notifying the students that the researcher would eventually see their answers. The questionnaire was distributed by the professor to get honest feedback from the students about whether or not they felt they were able to create a sustainable product as well as whether or not the guidelines and tool influenced their designs. The students' insight was extremely valuable to the success of this research project because it helped give direction toward refinements and revisions which would ultimately improve the guidelines and evaluation tool.

4.1.1 Interview Feedback

In general the feedback from the interview was positive, with nearly all the students seeing the value in guidelines such as these. One student suggested branding the guidelines and tool as other previous organization have. Up until that point the tool did not have a name or logo to distinguish itself from other projects such as Okala, LCA Calculator and ECO-it. This would also be crucial for web accessibility so the designers could easily remember the name and corresponding web address.

When asked about navigating the guidelines the students had mixed responses. In general they felt that it was clearly organized and the tab system worked well. There were some issues, however, if the designer were to get out of sequence then it would be hard for them to decide which questions they had answered and which were still left. The current layout was designed to be linear in that one design statement led to another, and one tab led to another. The design process, however, is usually anything but linear and the guidelines had to account for that. Other recommendations about navigating the tool included finding a way to more clearly distinguish which environmental principle the user was currently on. With the current system the page changes to the color of the icon for the particular environmental principle, as seen Figure 18, however instead of color there needed to be some kind of size or form change for the icon. Another recommendation about the format of the guidelines was that the students felt it needed to be better related to the circular form of the evaluation

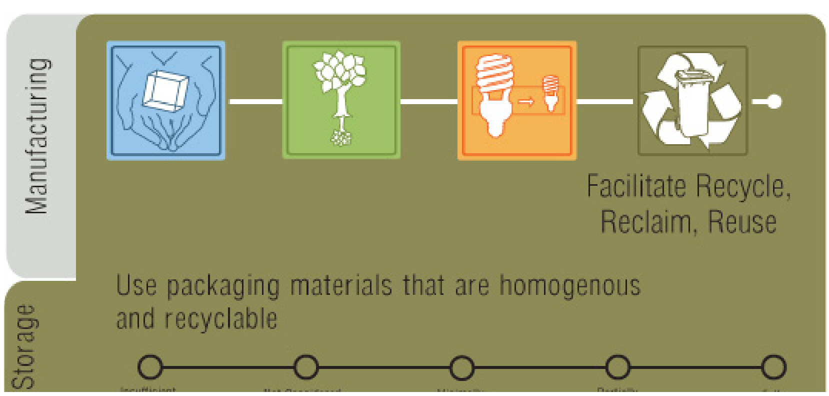

Figure 18: Icon Color Example

tool. In other words there was a disconnect between the tabular format of the guidelines and the circular evaluation tool. The students favored the circular format because all the life cycle phases and environmental principles were visible at once.

When asked about design improvements that would make the tool easier to use the students had many suggestions. In general they felt that some of the terms and concepts needed clarification. They advised using some form of pop-up windows or additional pages for additional information that could describe the various life cycle phases or environmental principles. For novice ecodesigners, this information could drastically improve the usability as well as the accuracy of the tool. Students also suggested incorporating URL links to websites that may give additional information such as, for example, a list of suppliers of eco-friendly materials. Another improvement the students suggested was making a paper copy of the guidelines available so that designers could reference them when they were away from the computer. Although they felt the evaluation tool should remain digital, the hard copy of the guidelines would be ideal for group work scenarios, during brainstorming or when access to a computer may be limited.

When asked whether they thought the guidelines (specifically the terms and icons) were easy to understand the students felt that some life cycle phases needed better explanation. For example, students were unclear as to whether or not the "Packaging, Storage, Distribution" phase included outer shipping cartons, point of purchase displays, casing for the product, and other accessories for shipping and display.

The last question the students were asked during the interviews was about the accuracy of the evaluation tool. Although this tool is meant to be applied to all types of products, it became apparent that two very different products may not be accurately compared. For example if a designer wanted to compare a canvas grocery bag with a gasoline-powered lawnmower there would be a difficult, inaccurate comparison. The students felt that the scores for two very different products could be similar and therefore misleading. This main objective of this tool, however, is for designers to make eco-friendlier design decisions for new products and eco-improvements on existing products and not necessarily for comparison between multiple categories of products. Nevertheless it was apparent that there were still some issues with the accuracy of the tool. In an instance where the product being evaluated did not have packaging there were several statements about recycling and using benign materials that did not apply. Although avoiding packaging altogether is often the most ecological choice, the answer choices were not reflected in the total number of green bubbles displayed in the evaluation tool. In essence, a product that had recycled packaging may seem more eco-friendly than a product that used no packaging at all. The same was true for products that did not use energy. There were several statements about the product use phase involving energy such as incorporating a standby mode, a low power mode or using efficient motors; however none of these statements applied if the product did not consume energy. These were all issues that needed to be resolved in the final version to help improve the accuracy of the tool.

In summary, the student feedback from the interview helped generate ideas and criticisms that ultimately led to guidelines and an evaluation tool that were easier to use and more accurate. The students felt there should be a better clarification of terms as well as supplemental information that may help the designer, they felt the navigation of the icons needed some improvement, they saw a need for a hard copy that the designer could print out, and lastly they saw a need for improvements in some of the statements in order to achieve more accurate ratings.

4.1.2 Questionnaire Feedback

The questionnaire distributed by the professor asked a question about whether or not the students felt they were able to successfully design a sustainable product concept. Ten of the 16 students responded to the questionnaire and nine said that they thought they were able to design a sustainable product. A statement made by one student was that sustainability was understood as a concept; however there was limited success in being able to apply all aspects of eco-design. Another response made by one student was that the guidelines were a good checklist to make sure that all aspects of sustainability were covered.

Due to the fact that the students were participating in a studio class emphasizing sustainability, there were challenges as to discovering whether or not the students were able to create sustainable products from the developed guidelines or from the course material and curriculum. To resolve this, the next question from the questionnaire asked whether or not they chose to use the guidelines to help assist them in their concept generation phases. Out of the ten designers answering the survey only four said they used the guidelines during concept generation. Two respondents said they did not use the guidelines because they did not want constraints during the brainstorming process, and two individuals used other forms of guidelines (LCA and Okala) as their design parameters. A statement made by one student was that sustainability was understood as a concept through participating in the class, and there was no desire to use the guidelines for additional assistance. Out of the four participants who stated that they used the guidelines two said that they were used in conjunction with other resources such as LCA and Okala which were supplied in class from their professor. Another student used the guidelines during developmental phases, however not all aspects applied because the product which was created did not use energy to operate.

The last question the students were asked was, "If you used the guidelines and evaluation tool, do you have an example of an aspect of the design that was influenced by it? Out of the ten respondents, seven stated either 'no' or 'not available' because they did not use the tools, and three responded yes. One of the 'no' respondents stated using the evaluation tool at the end of the project however it was too late to make any necessary changes because the project was over. Out of the three respondents that answered 'yes,' one stated that their group was able to achieve conservation of materials in manufacturing and eliminated packaging, another respondent said that their group was able to optimize the end of life circumstance for the product, and the last respondent said their group was able to reduce energy consumption during product use.

The feedback from the questionnaires appeared to be honest and candid. As compared to the interview, the feedback from the questionnaire revealed reluctance to use the guidelines and evaluation tool. There were numerous reasons why only four designers used the guidelines during concept generation, however most of the reasons were because the designers did not want to be restricted in the brainstorming process or because they used other forms of tools such as Okala and LCA. Other reasons may have had to do with the time frame of the project which was only two weeks. The fact that they had numerous resources to reference may also have discouraged them from trying the new guideline system. This is one area where using practicing designers versus students in a sustainability class for research subjects would have proven beneficial. Practicing designers, for example, may not have access to the same resources and tools the student designers had access to. Also, because the student designers were participating in a project, when they evaluated the designs at the end there was no time to go back and modify the products. This would likely be different in a professional setting where products and concepts are evaluated numerous times before they are manufactured.

4.2 Guideline and Evaluation Tool Refinement

Inspired by the students comments, there were numerous revisions made to the guidelines and evaluation tool system. The tools are meant for designers of all levels of eco-design expertise, therefore the refinements were crucial in the effort of improving

Figure 19: Eco-Logic Logo

the usability and accuracy of the tools.

The first matter to resolve was the issue of branding the guidelines and tool. As mentioned earlier, this would be an important characteristic for helping designers remember the tool as well as the web address for the application. As a result, the guidelines and tool system was named Eco-Logic. The logo, which is a circle half filled with green, represents that there are opportunities for eco-design improvements in all products.

The students also raised concern over the disconnect between the book-like style of the guidelines, as seen Figure 16 and the circular format of the evaluation tool

Figure 20: Guidelines Final Revision

shown in Figure 17. The book format was reconsidered and ultimately changed to the same circular format as the evaluation tool as seen Figure 20. This new circular format creates an interesting visual shape on the page, as most web applications are standard landscape format pages. This shape allows all the life cycle phases and corresponding environmental principles to be visual at once. In the previous version, the designer was unaware of what information was concealed behind each tab. Also, when the final answers are submitted, the guidelines transform into the evaluation tool which outputs the final product score. There is no longer a switch from rectangular format to the circular format.

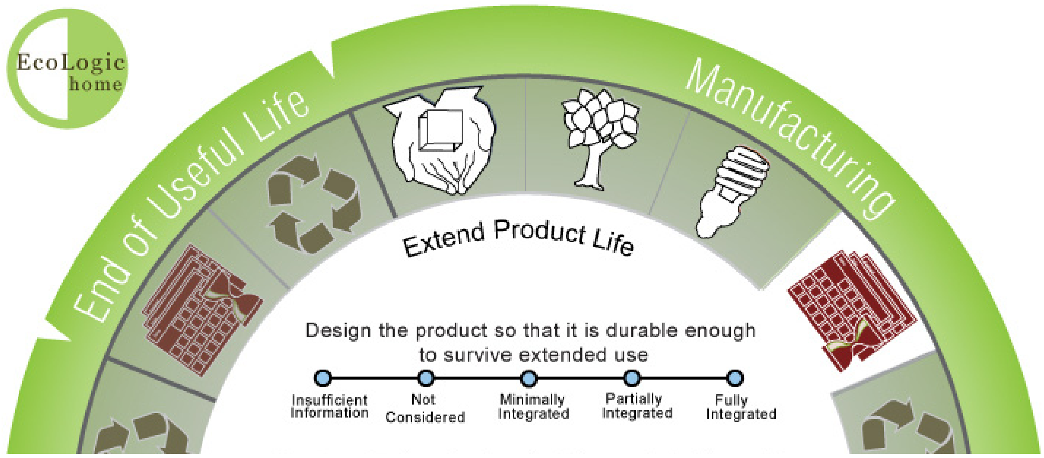

Figure 21: Answered Icons

In addition to the shape of the tool, the tab navigation system was replaced by a rotating grey ring which signifies which icon the user is currently on. As mentioned earlier, this helps the designer visually determine where they are in the process of completing the whole system, and it allows them to easily jump from one principle to another. To advance to the next page of guidelines the user can click the next icon and the ring will rotate. In previous versions of the guidelines there was no indication as to which icons the user had already answered and which were unanswered. To help resolve this issue the revised guidelines have icons which lose their original color, as seen in Figure 21, and change to black and white once they have been completed. This system does not prohibit the user from going back to the page and revisiting or editing their answer choices, however it allows them to easily see which icons they have answered. This is especially important for users who choose to answer the guidelines out of their sequential clockwise order.

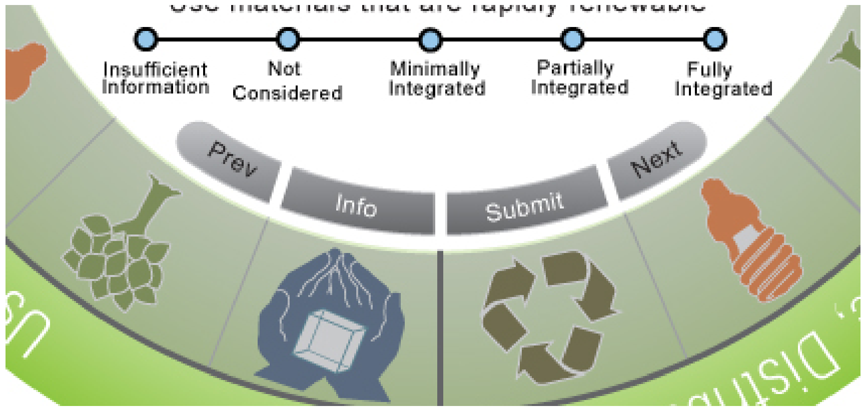

Figure 22: Navigation Buttons

As seen in Figure 22, another navigation aid was the addition of buttons at the bottom of each guidelines page. If the user chooses not to manually select the next environmental principle icon, they can simply click the ‘Next’ button. At the conclusion of their guidelines session they can click ‘Submit’ to generate the evaluation tool with their product’s results.

Some of the students also felt there was a need for supplemental information to be displayed within the guidelines document. The eco-design strategy statements are meant to give the designer direction and inspire environmentally conscious design innovations. For novice eco-designers, however, they may need more information that could help inform their answer choices as well as possibly offer advice about implementing the eco-design strategies. To account for this, an information button was added to the navigation bar, as seen in Figure 22. The user could choose the button and be directed to a page containing more detailed information specific to the selected environmental principle and life cycle phase. The information page, as seen in Figure 23, would also supply the designer with suggested sources and literature which could help them better understand and apply the eco-design strategies.

The guidelines and evaluation tool evolved into many forms throughout this research project. After receiving feedback from the students, the guidelines took the largest departure from their original form and several characteristics were added that will hopefully enhance the overall look and usability or the product.

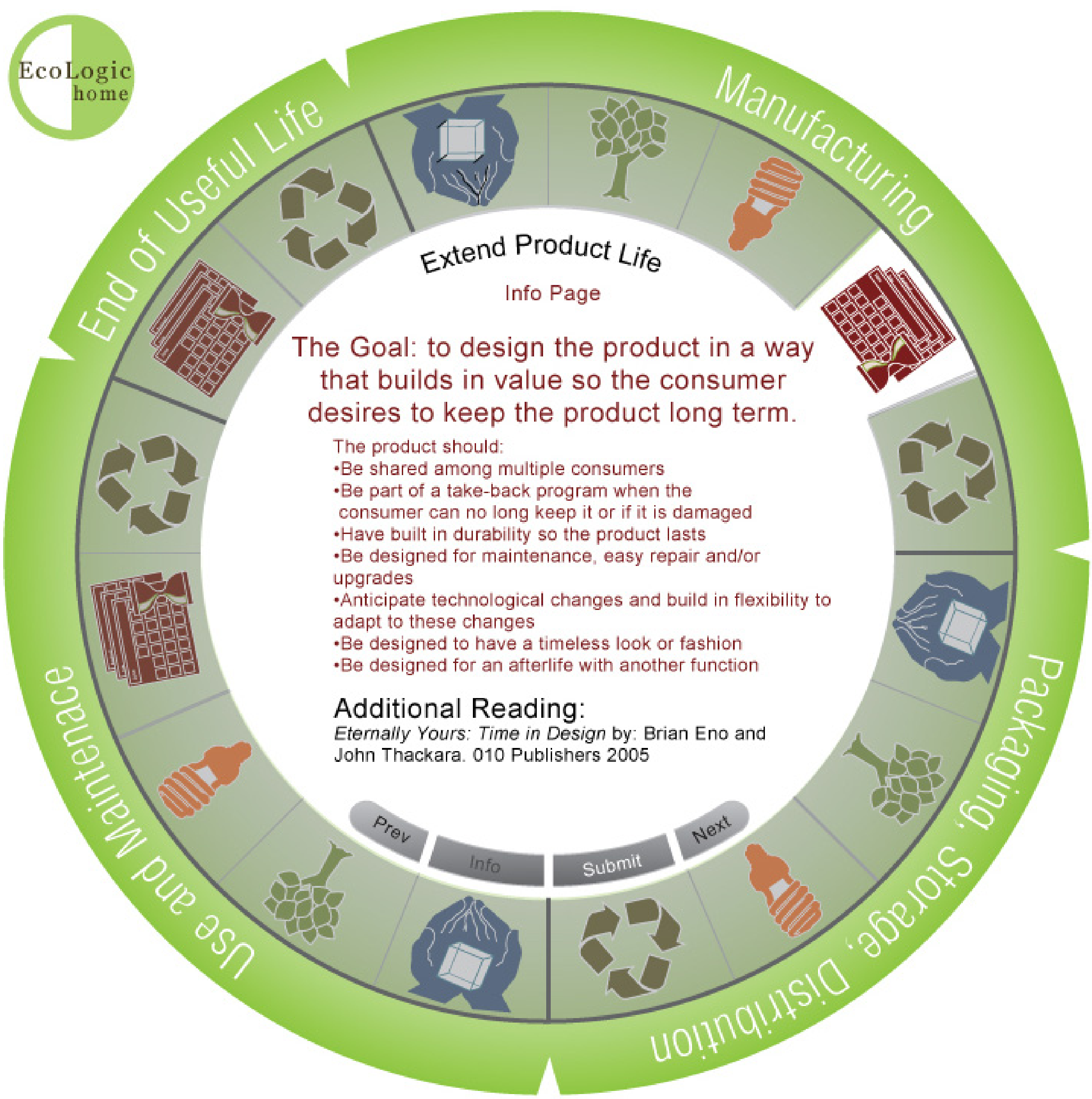

Figure 23: Guidelines Information Page

CHAPTER 5

ANALYSIS

5.1 General Project Analysis

The purpose of this project was to determine the effectiveness of guidelines and a product evaluation tool in assisting the implementation of eco-design principles. Although this research project had limitations, its intent was to recognize industrial designers as catalysts for environmental improvement. This project will be deemed successful even if the guidelines and evaluation tool are never publicly launched, if it creates more public awareness about eco-design principles. An industrial designer may not have a passion for environmental preservation, but if they can be given tools for implementing eco-design principles, they may be put on the right path to create a product with value-added characteristics and innovations that are also beneficial for the environment.

5.2 Weaknesses of the Research Methods

After reflecting on the research results and student feedback, it was apparent that there were weaknesses in the research methods which led to limitations in the study. First of all, graduate student designers were used as participants instead of practicing designers. This proved to be disadvantageous because of differences in their resource accessibility as well as the extensiveness of their projects. The students were a convenient and reliable subject pool and it was expected that they would gain additional knowledge about sustainability and eco-design as well as benefit a research project. Practicing industrial designers, however, would likely have more time to work on projects and therefore would have more opportunities to refine projects. Also, practicing designers may also be motivated by real world constraints such as money and business reputations. These may or may not influence eco-design implementation. Future research should include a more representative sample of practicing designers performing actual design tasks over a longer period of time.

In addition to using practicing designers it would also be beneficial to include a control group for the research. If the research was to be repeated, the results would be more internally valid if there were three separate research groups. One group would have access to the guidelines and tool, another group would have access to a separate tool like, for example, Okala, and another group would work as they typically would without any eco-design assistance. The products from all three groups could then be analyzed and compared to see which group developed more environmentally friendly product designs.

5.3 Future Considerations

If this project were to be continued there would be certain considerations which could be addressed. For example, with the creation of the evaluation tool there was no key or frame of reference for the product's final score. A low product score, an average product score and a high product score would have to be determined so the designers would know how their product compares to other products. Although this tool is meant for self reflection and for designers to be able to choose among alternative designs, there may be an instance when the designer wants to compare the design to existing designs in the marketplace. At this time there is simply an output of colored bubbles and a final score, but no analysis to help designers determine which areas would be the most beneficial to improve. A system to develop a hierarchy of environmental principles would help designers prioritize which areas of eco-design to implement. This would be a crucial step in the research process to help designers recognize their product's environmental impact.

Another future consideration which could prove beneficial for practicing designers would be to expand the resources on the guidelines information pages. For example, there could be listing of suppliers or manufacturers who offer benign materials, recycled packaging, energy efficient services and other resources for product manufacturing. The guidelines would then become an all inclusive source of eco-design principles as well as resources where designers and manufacturers could connect with suppliers of sustainable goods and services.

5.4 Conclusion

Despite some limitations in testing of the guidelines and evaluation tool, the information gained can be used to promote eco-design and inspire similar future research. Each product designed will undoubtedly have an impact on the environment; the extent of its impact, however, lies in the hands of the designer. As the world's population continues to increase and natural resources continue to decrease, industrial designers will be important catalysts for more efficient and economically viable design.

APPENDIX A: RESEARCH INSTRUMENT DOCUMENTATION

1. **Design Improvements: What would make this tool easier to use for practicing designers?**
2. **Was navigating the tool easy or difficult? What made it easy/difficult?**
3. **If you were a practicing industrial designer would you likely use these guidelines and tool? Why or why not?**
4. **Was the evaluation tool easy to understand and calculate?**
5. **How did you feel about the accuracy with the tool? Do you think your rating was an accurate reflection of your product? Why or why not?**

Figure 24: Student Interview Questions

1. **With the completion of the first project, do you feel that you were able to successfully design a sustainable product concept?**
2. **Did you use the guidelines during concept generation? (If no, explain why)**
3. **Did you use the evaluation tool at the completion of the design? (If no, explain why)**
4. **If you used the guidelines and evaluation tool, do you have an example of an aspect of the design that was influenced by it?**

Figure 25: Follow-Up Student Questionnaire

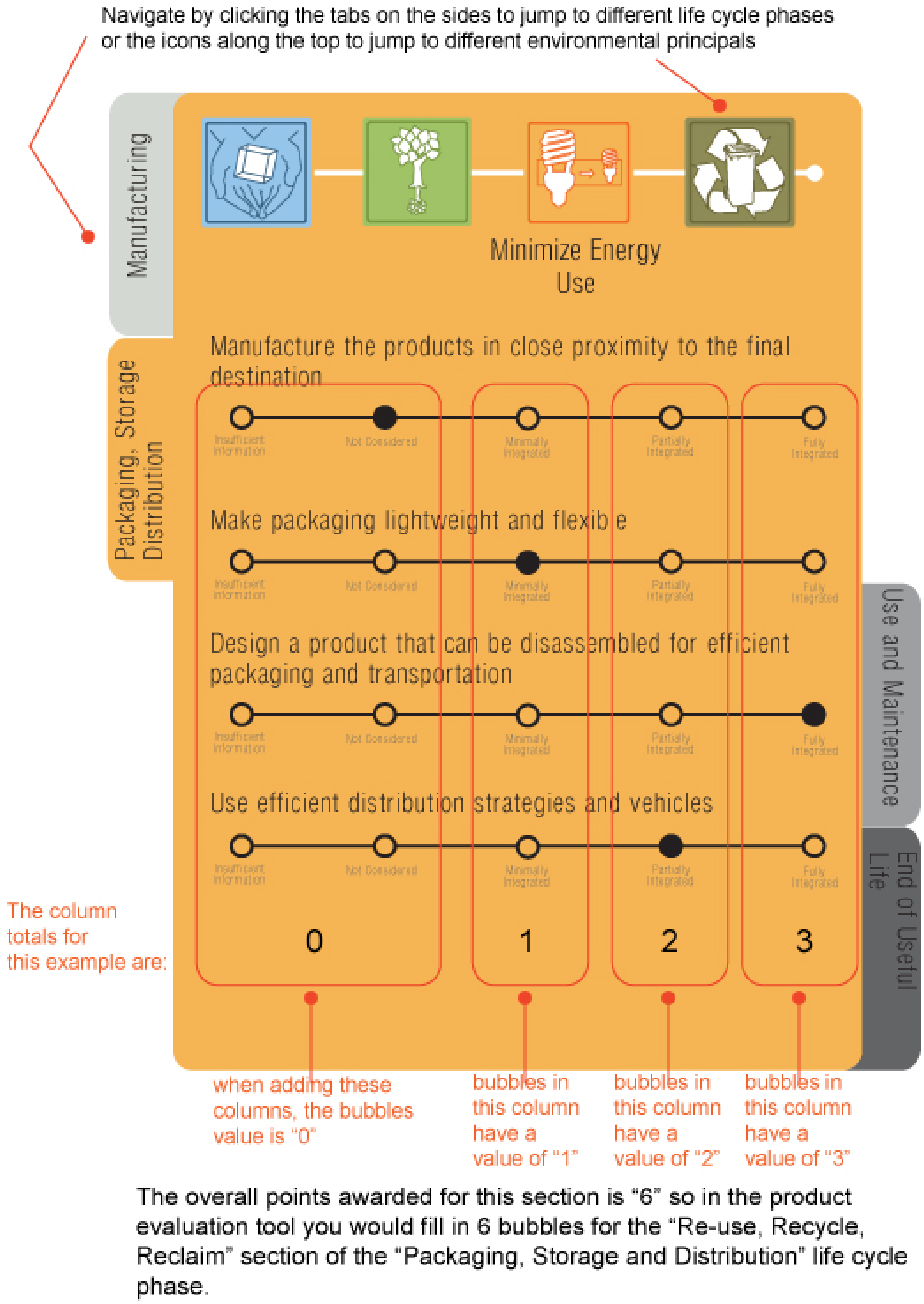

Figure 26: Evaluation Instructions

APPENDIX B: GUIDELINE PAGES AND EVALUATION TOOL IMAGES

Figure 27: Manufacturing, Benign Materials

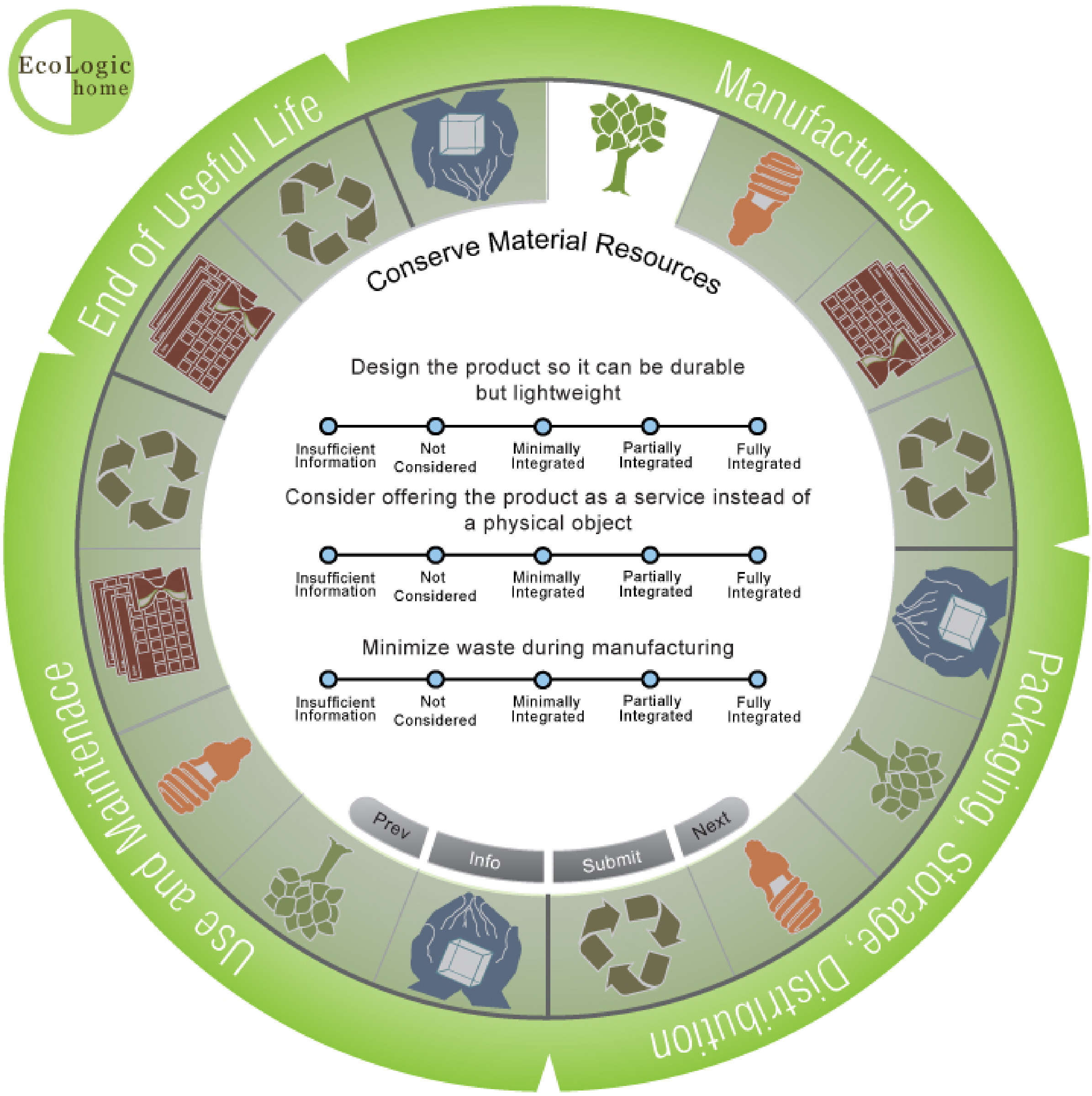

Figure 28: Manufacturing, Conserve Material Resources

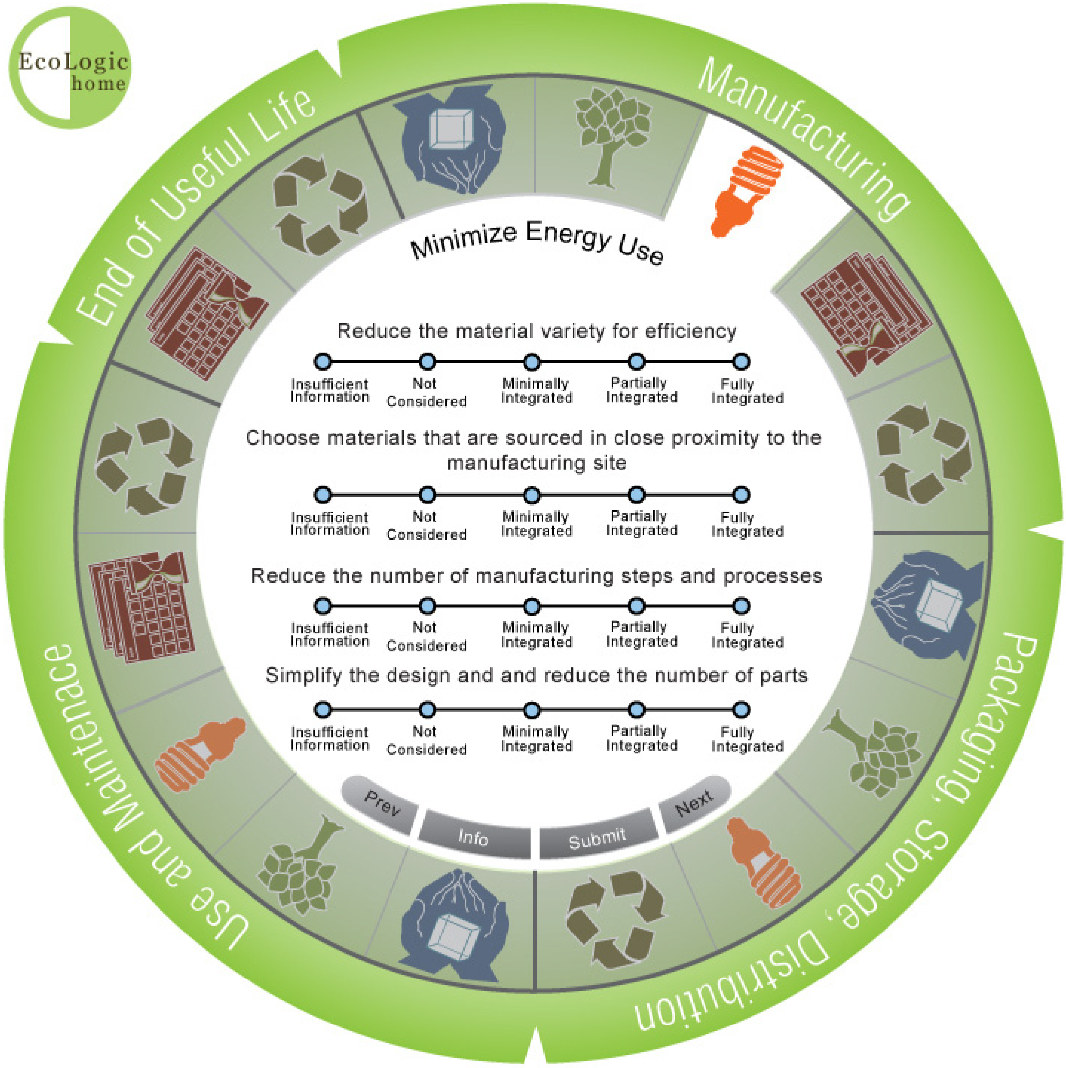

Figure 29: Manufacturing, Minimize Energy

Figure 30: Manufacturing, Extend Product Life

Figure 31: Manufacturing, Recycle, Reclaim, Re-use

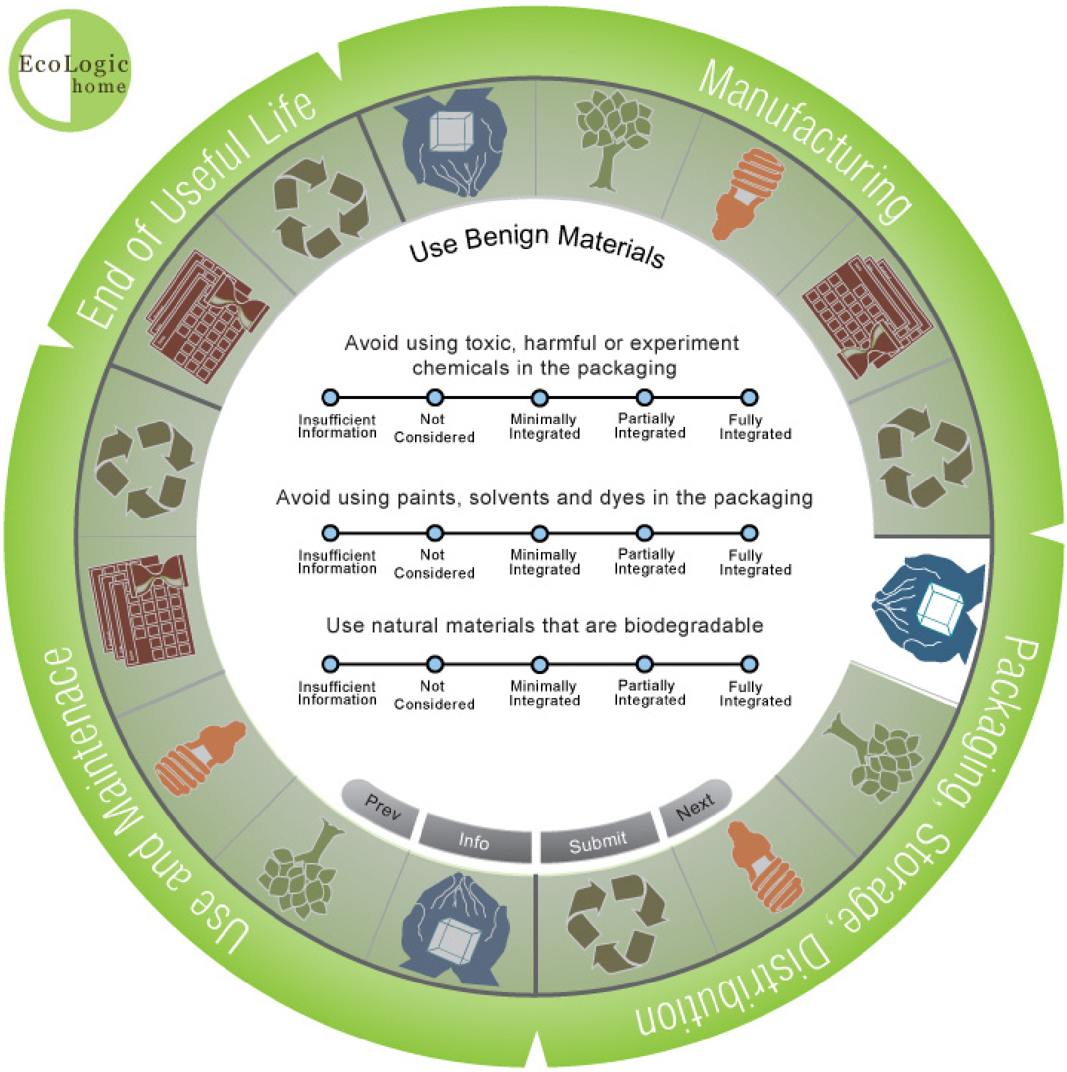

Figure 32: Packaging, Benign Materials

Figure 33: Packaging, Conserve Material Resources

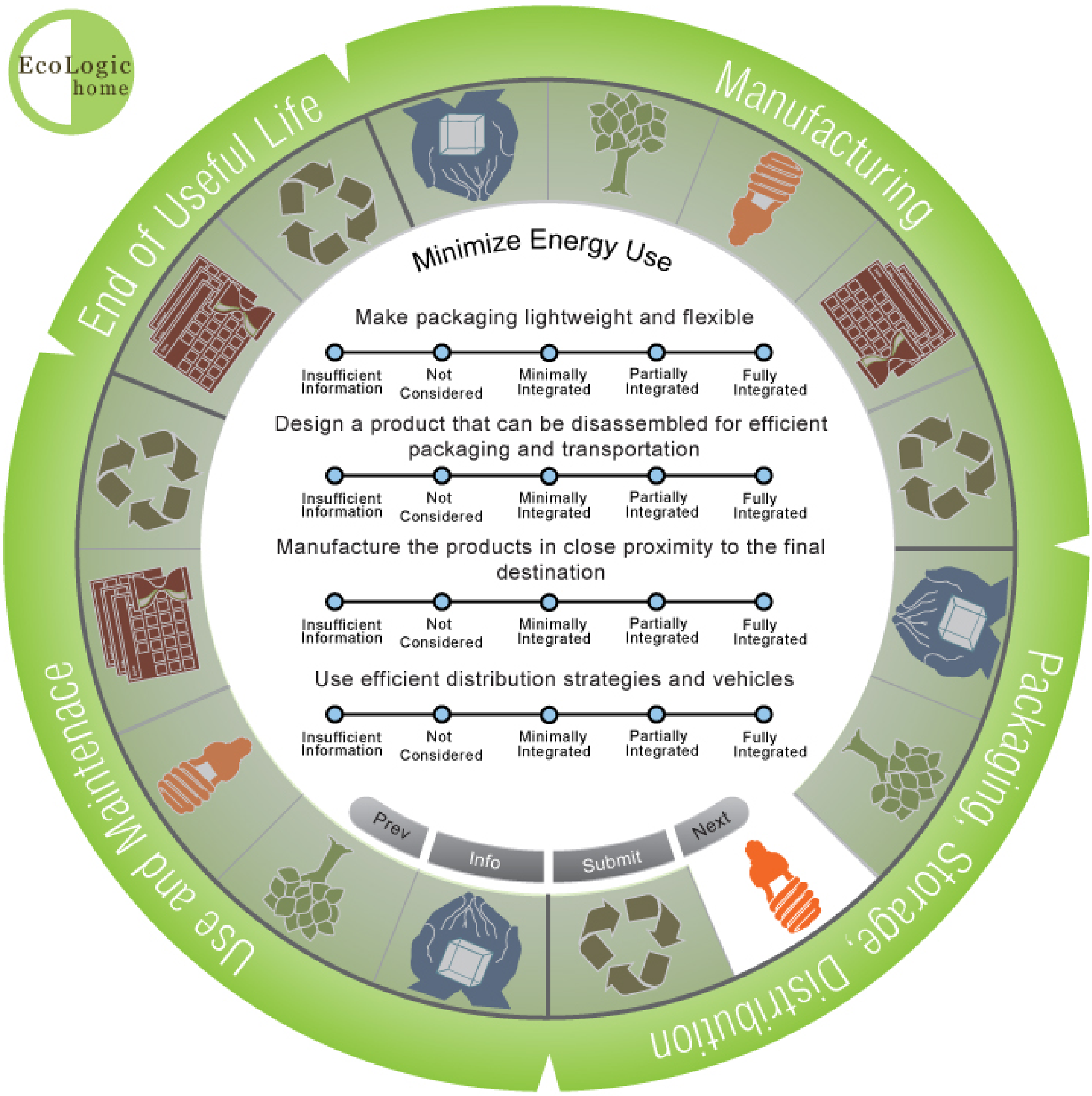

Figure 34: Packaging, Minimize Energy

Figure 35: Packaging, Minimize Energy

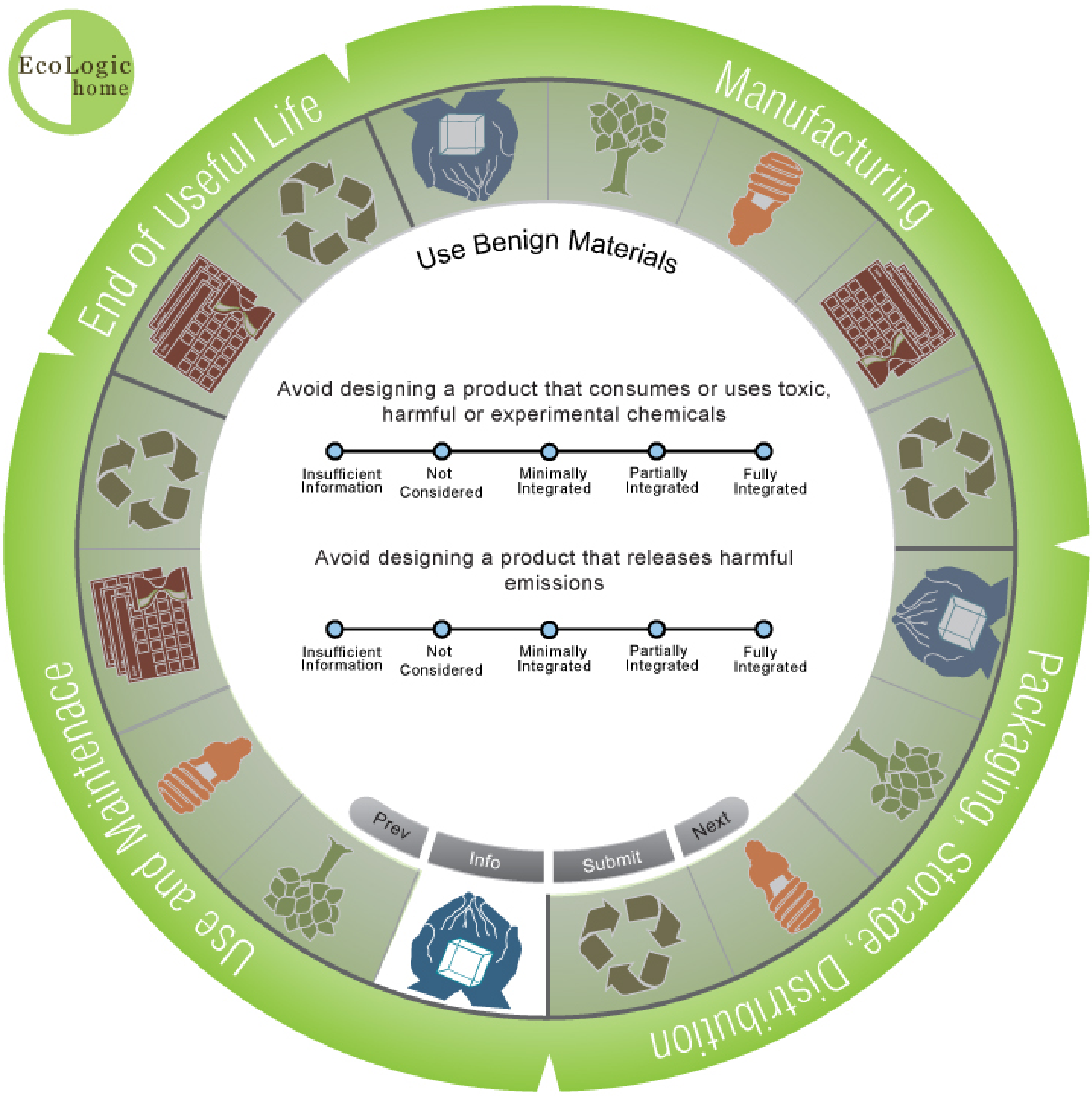

Figure 36: Use and Maintenance, Benign Materials

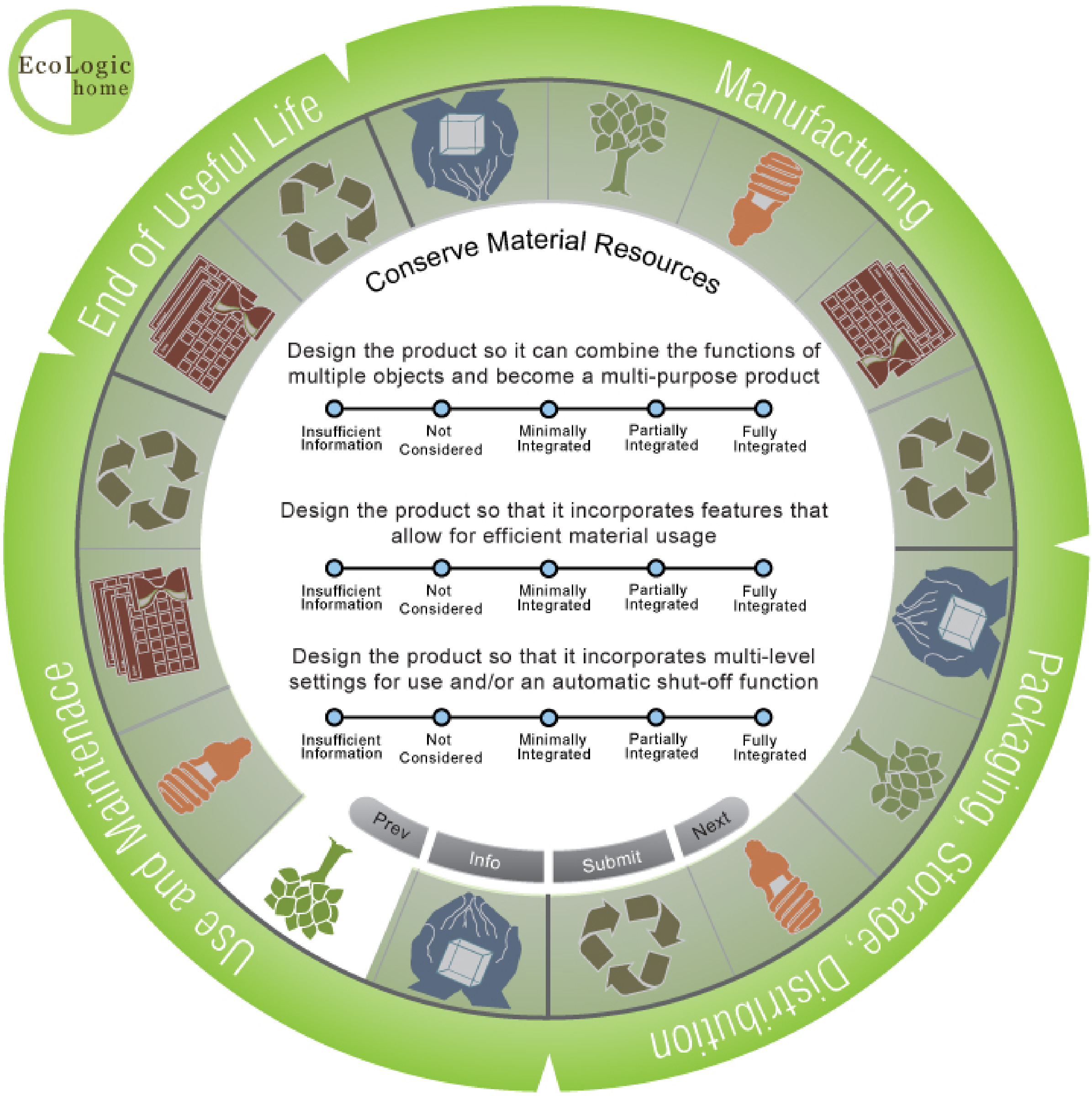

Figure 37: Use and Maintenance, Conserve Material Resources

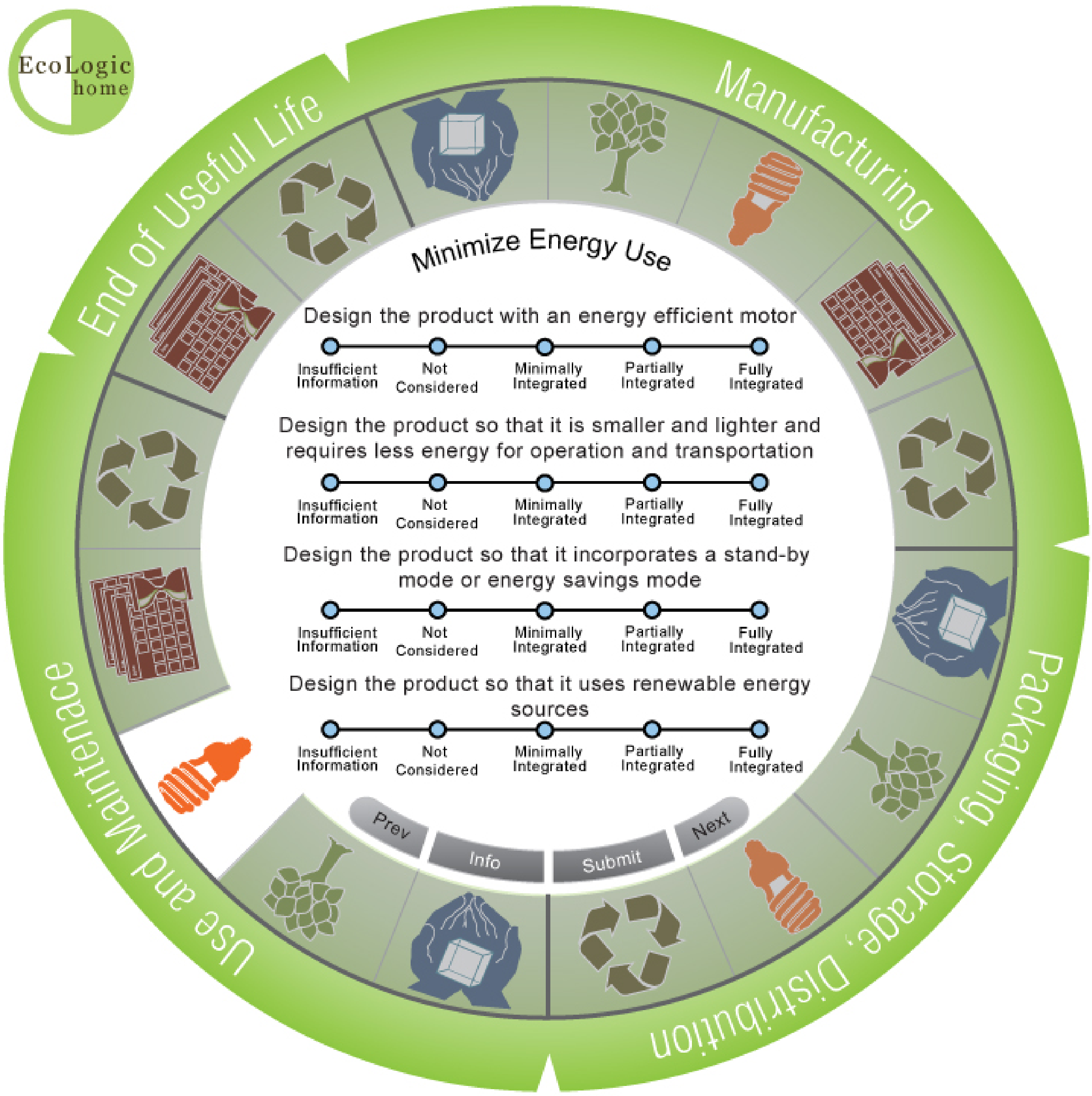

Figure 38: Use and Maintenance, Minimize Energy

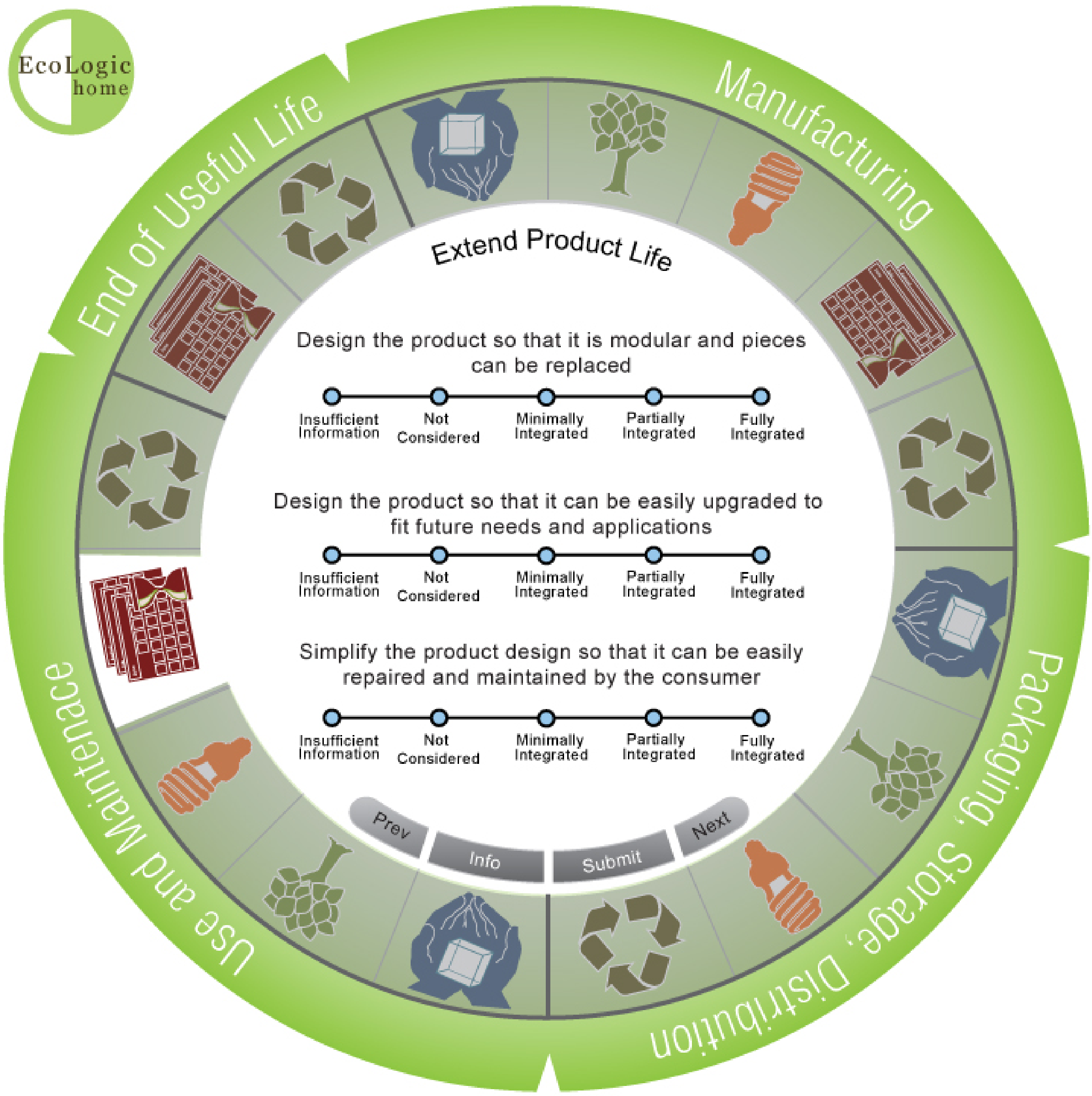

Figure 39: Use and Maintenance, Extend Product Life

Figure 40: Use and Maintenance, Recycle, Reclaim, Re-use

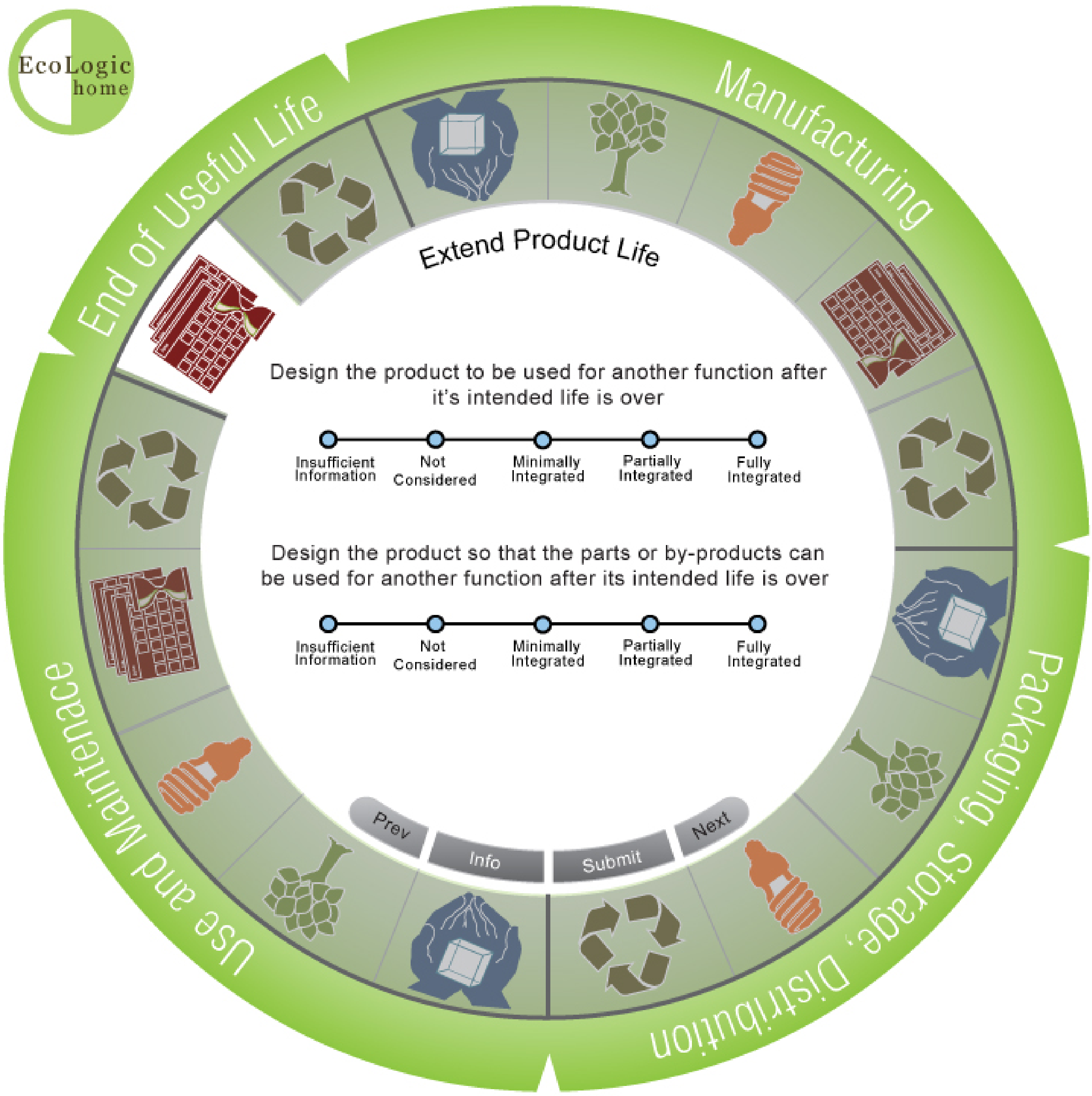

Figure 41: End of Useful Life, Extend Product Life

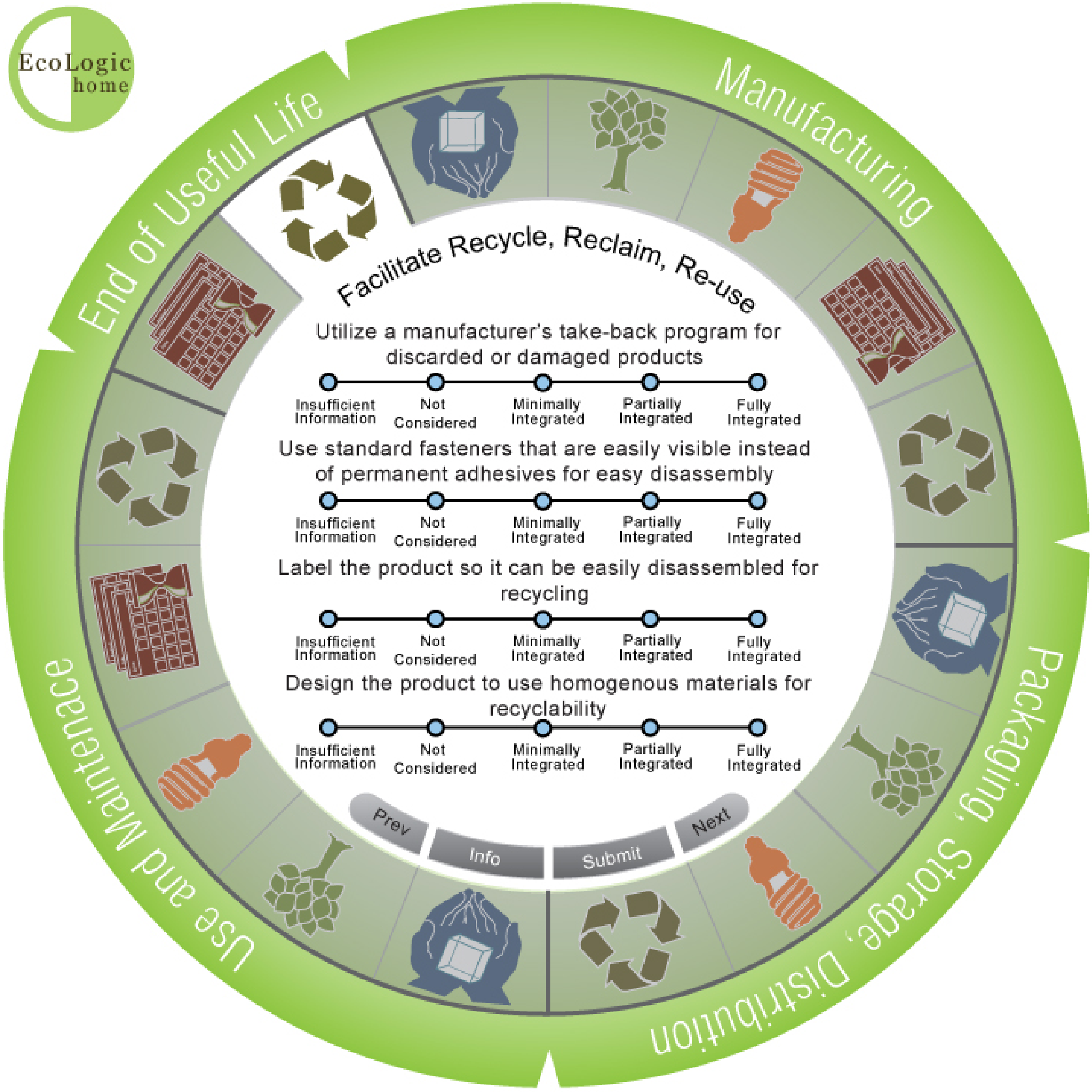

Figure 42: End of Useful Life, Recycle, Reclaim, Re-use

Figure 4319: Evaluation Page Example

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